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SECTION-B.

PART III

ON THE MORPHOLOGY OF LEMON-BUTTERFLY
PAPILIO DEMOLEUS (LEPIDOPTERA)

PART I. SKELETO-MUSCULAR MECHANISM (HEAD AND ITS
APPENDAGES)

By

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INTRODUCTION

Papilio demoleus is a pest of citrus plants and is found in India almost throughout the year. Its convenient size and easy availability render it an excellent insect type for dissection by the post-graduate students of the Indian universities. But unfortunately neither the morphology of this insect nor that of any allied form has so far been worked out—infact, the work in Lepidoptera in general is scanty, notwithstanding the fact that this order forms one of the most highly evolved groups of insects. The works of earlier authors, like Burgess (1880), Jackson (1890), Kellogg (1893, '95) and Petersen (1900) being old, are not easily available. Recent workers like Philpott (1927), Snodgrass (1935), Schmitt (1938), Pradhan and Aren (1941), Rakshpal (1944), Short (1951), Eastham and Eassa (1955) and Srivastava (1956) have studied only some particular aspects of the morphology, while Madden's (1944) account is rather sketchy. A complete morphological study of a particular species has consequently been lacking. The present studies are an attempt in that direction.

The author wishes to acknowledge his grateful thanks to Dr. R. Rakshpal for suggesting the problem and supervising the work. His thanks are also due to Prof. M. B. Lal, Head of the Zoology Department, for providing facilities to carry out the work.

Head

(i) External features of the head :

The head is an unsegmented subglobular capsule covered all over with hairs and scales and carries the antennae, the eyes, the functional mouth and the proboscis. The antennae are dorsal in position and the large compound eyes occupy the whole of the lateral margins of the head. As the mouth-parts are directed ventrad, the head becomes *hypognathous*. The long proboscis remains closely coiled around a horizontal axis beneath the head when not in use. On either side of the proboscis is a hairy labial palp. The two palpi become recurved and touch the face. The face has a hairy yellowish band on either side.

(ii) Areas of the cranium.

The cranial areas are not clearly defined as some of the sutures have become obliterated. However, the following areas can be distinguished:—

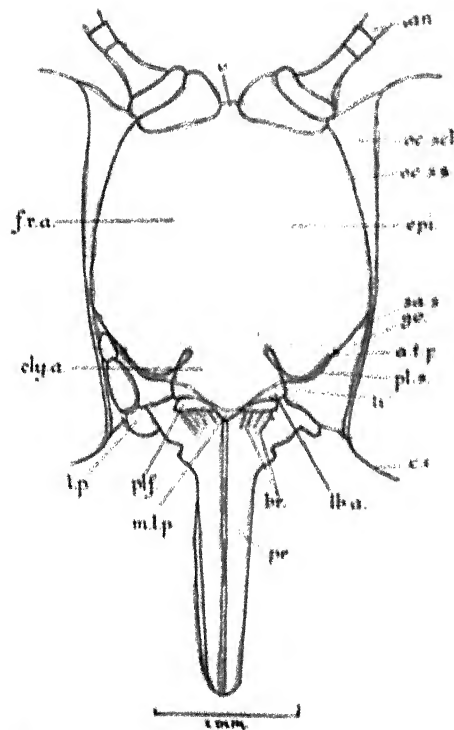


Fig. 1. Facial view of the head. *a. t. p.*, anterior tentorial pit; *an.*, antenna; *br.*, bristles; *c. e.*, compound eye; *cl. u.*, area; *epi.*, epistoma; *fr. a.*, frontal area; *ge.*, gena; *l. p.*, labial palp (right side only); *lb. a.*, labral area; *li.*, line due to greater sclerotization of labral area; *m. l. p.*, median labral protuberance; *oc. s. s.*, oculo-subantennal sulcus; *oc. sel.*, ocular sclerite; *plf.*, pilifer; *pl. s.*, pleurostomal suture; *pr.*, proboscis; *sa. s.*, subantennal sulcus; *v.*, vertex.

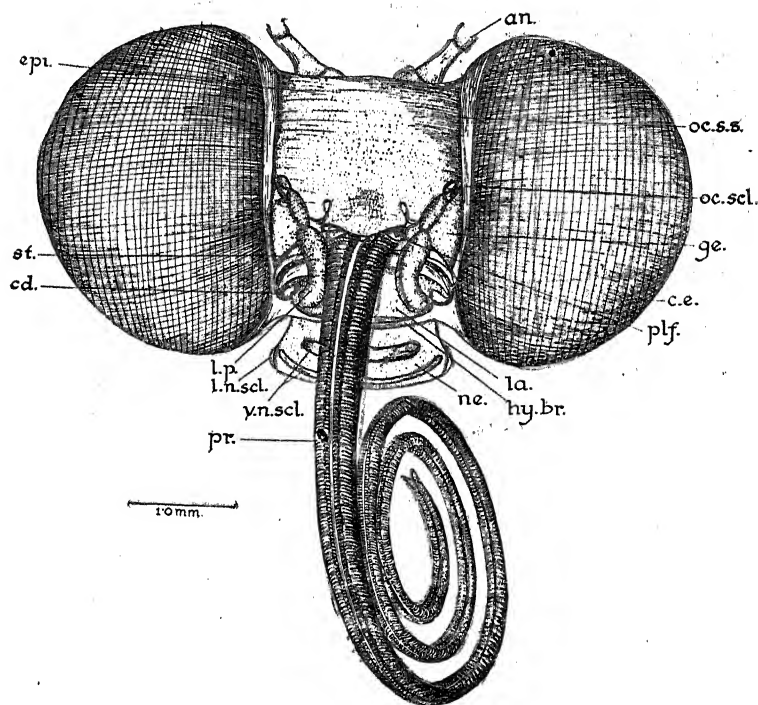


Fig. 1-A. Head-capsule of *Papilio demoleus* (semidiagrammatic). *cd.*, cardo; *hy. br.*, hypostomal bridge; *l. p.*, labial palp; *l. n. scl.*, lateral neck sclerite; *la.*, labium; *ne.*, neck region; *st.*, stipes; *v. n. scl.*, ventral neck sclerites. Remaining abbreviations same as Fig. 1B.

The *epistoma* (Fig. 1) is a large, sub-quadrangular and slightly convex plate forming the entire facial region. It is composed of three sclerites—the frons, the clypeus and the labrum which have fused with each other leaving no traces of their demarcating sutures. The epistoma has so far been regarded by various authors (Snodgrass 1935, Imms 1938, Pradhan and Aren 1941) as the fronto-clypeus with the assumption that the clypeus forms the greater part of it. But no attempt has been made to establish the dividing limits between them. Du Porte (1946) while tracing the evolution of a pterygote cranium establishes the criteria that the portion of the face above the anterior mandibular articulations is the frons and that below it, the clypeus. The anterior mandibular articulations always lie immediately below the anterior tentorial pits. As the mandibles are entirely wanting in *P. demoleus*, the anterior tentorial pits may be taken as the criteria for demarcating the limits of the frons and the clypeus. Thus the area below the line formed by joining the two anterior tentorial pits becomes the clypeus and the comparatively larger area above the line, the frons. Snodgrass (1935: 119) keeps the origin of the head muscles as the basis for demarcation of the limits of the sclerites. According to him, the clypeus gives origin to the cibarial dilators and the frons to the pharyngeal dilators. The fact that the cibarial dilators in *P. demoleus* also originate within the level of the anterior tentorial pits and the pharyngeal dilators above this level further support my basis of demarcation of the clypeus from the frons. The frons is bounded laterally by the subantennal sulci but its dorsal limit is not distinctly marked. It is, however, probable that the line, formed by joining the dorsal ends of the occipito-postgenal

sulci, demarcates it dorsally. The clypeus is bounded laterally by the pleurostomal sutures while its ventral limit can be established by the place of origin of the first cibarial dilator. The narrow area ventral to this muscle is the reduced labrum which is slightly submarginal, more strongly sclerotized and bears the paired pilifers. The *vertex* is the narrow area between the two antennal bases formed by the frontal and the occipital portions.

The *genae* (Figs. 1 and 2) are a pair of triangular sclerites, each of them lying between the eye and the lower portion of the epistoma. The outer margin of the sclerite is demarcated by the ocular sulcus, the upper margin by the pleurostomal suture together with the free part of the subantennal sulcus, while the lower margin by the hypostomal suture. The lower part of each gena bends inwards to form the ventro-lateral wall of the cranium.

The *subgenae* (Fig. 2) are a pair of narrow submarginal areas one on either side of the floor of the cranium. They are somewhat shelf-like supporting the maxillae on their lateral aspects. The outer margin of each subgena is demarcated by the hypostomal suture.

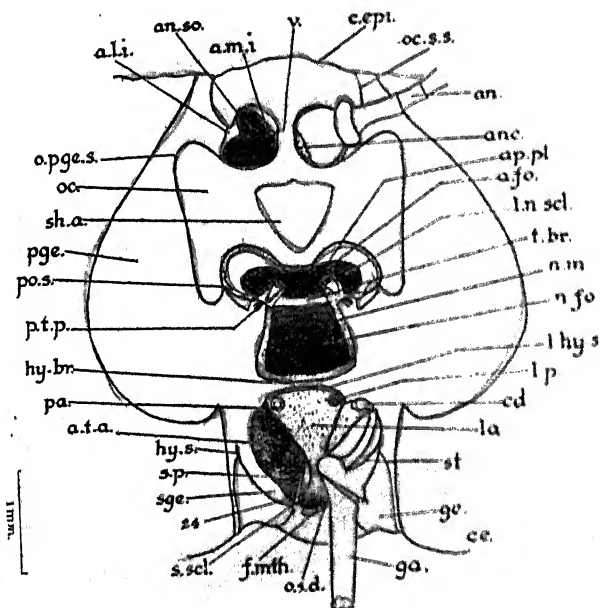


Fig. 2. Postero-ventral view of the head after stretching. *a. fo.*, alaforamen; *a. l. i.*, antero-lateral inflection of the rim of antennal socket; *a. m. i.*, antero-mesal inflection of the same; *a. t. a.*, anterior tentorial arm; *an.*, antenna; *anc.*, antacorium; *an. so.*, antennal socket; *ap. pl.*, apodemal plate of post-occipital sulcus; *cd.*, cardo; *c. e.*, compound eye; *c. epi.*, cut margin of epistoma; *f. mth.*, functional mouth; *ga.*, galea; *ge.*, gena; *hy. br.*, hypostomal bridge; *hy. s.*, hypostomal suture; *l. hy. s.*, labio-hypostomal suture; *l. n. scl.*, lateral neck sclerite; *l. p.*, labial palp (cut); *la.*, labium; *n. fo.*, neuroforamen; *n. m.*, neck membrane; *o. s. d.*, opening of the common salivary duct; *o. pge. s.*, occipito-postgenal sulcus; *oc.*, ceciput; *oc. s. s.*, oculo-sub-antennal sulcus; *p. t. p.*, posterior tentorial pit; *pa.*, paracoila; *pge.*, postgena; *po. s.*, postoccipital sulcus; *s. scl.*, suspensorial sclerite; *s. p.*, sucking-pump; *sh. a.*, shield-shaped area of postocciput; *sge.*, subgena; *st.*, stipes; *t. br.*, tentorial bridge; *v.*, vertex; 24, suspensorio-salivary muscle.

The *postgenae* (Fig. 2) are a pair of large sclerites forming the whole of the postero-lateral and the outer portions of the ventral wall of the cranium. It is demarcated from the occiput by the prominent occipito-postgenal sulci. An antero-posterior elongation of the postgenal regions is accompanied by a proportionate elongation of the occipital foramen itself so that the proximity of the foramen with the labial base is maintained, though they remain separated from one another by a narrow bridge developed by the mesal extensions and fusion of the hypostomal lobes of the postgenae.

The *occiput* (Fig. 2) is bounded by frons dorsally, laterally by the occipito-postgenal sulci and posteriorly by the postoccipital sulcus. The central area of the occiput is shield-shaped and is relatively less sclerotized than the surrounding area.

The *ocular sclerites* (Fig. 1) are paired, each lying between the compound eye and the epistoma and demarcated by the ocular sulcus. On the back of the cranium these sclerites merge with the postgenae and ventrally they become very narrow getting almost obliterated.

(iii) Sulci and sutures of the cranium.

Some of the sutures of the cranium have become obliterated due to the fusion of sclerites and those that are present are mostly "groove sutures" or sulci because they mark the positions of the sclerotized inflections or internal ridges. The following sulci and sutures can be marked:—

The *postoccipital sulcus* (Fig. 2) is well marked surrounding the upper half (or alaforamen) of the occipital foramen. At the end of each arm lies the posterior tentorial pit. The lateral portion of the sulcus has infolded in a horizontal direction to form the two half-moon shaped apodemal plates, one on either side of the alaforamen, giving insertion to the neck and the prothoracic muscles. Due to this infolding, the postocciput has been reduced to a mere thickened line which gives attachment to the neck membrane.

The *occipito-postgenal sulci* (Fig. 2) are paired separating the occipital and the postgenal areas. Each sulcus originates from the lower portion of the arm of the postoccipital sulcus, runs dorsalwards, makes a bend and then runs along the inner margin of the antennal socket.

The *subgenal sutures* (Fig. 1 and 2) are paired, each of them runs on the ventro-lateral wall of the cranium from a point anterior to the paracoila, traverses the outer margin of the subgena, arches over the face between the gena and the epistoma, finally ending below the anterior tentorial pit. The suture is divisible into two parts: the first part which runs on the outer margin of the subgenal area is known as the *hypostomal suture* and the second part which runs on the facial aspect upto the anterior tentorial pit is the *pleurostomal suture*.

The *ocular sulci* (Fig. 1) are also paired, running on each side of the head between the compound eye and the epistoma, thus surrounding only the facial side of the eyes. The upper three-fourth of the sulcus is merged with the subantennal sulcus. Therefore, this combined part of the two sulci may be termed as the *oculo-subantennal sulcus*. The ocular ridge is broad and extends between the antennal base and the postgena. The upper three-fourth of this ridge also remains fused with the subantennal ridge. The ocular ridge is probably the same as the "ocular diaphragm" of Ferris (1942).

The *subantennal sulci* (Fig 1) are paired, each of them extending between the anterior tentorial pit and the antennal socket. But only the lower one-fifth of the sulcus is separately visible, the rest of it being merged with the ocular sulcus. The subantennal ridge is as broad as the ocular ridge and the free margins of the two ridges, though united, can be easily separated. The ventral end of the subantennal ridge is fused with the base of the anterior tentorial arm.

The subantennal sulci have also been designated as the subocular and fronto-genal sutures. Du Porte (1946) has dealt at length on the importance of the fronto-genal sutures in defining the lateral limits of the frons. In a recent (1956) contribution he modifies his view to mention that the ventral descent of the genal regions results in the formation of other sutures, the *clypeo-genal sutures*, between the clypeus and the genae. Thus what he previously regarded as the fronto-genal suture is, in fact, the composite latero-facial suture formed by the union of fronto- and clypeo-genal sutures. Evidently the clypeo-genal suture of Du Porte corresponds to the pleurostomal portion of the subgenal suture in case of *P. demoleus*. The reasons for regarding it as the subgenal suture and not the clypeo-genal suture are : (i) each anterior tentorial pit is normally situated at the dorsal end of the subgenal suture and not of the clypeo-genal suture ; (ii) the clypeo-genal suture, according to Du Porte, extends between the anterior tentorial pit and the clypeo-labral suture. In this case, the two sclerites being fused, there is no clypeo-labral suture and that the subgenal suture extends much beyond the labrum on the ventro-lateral wall of the cranium.

(iv) Antennae and their muscles.

The antennae (Fig. 3) are a pair of long and club-shaped structures occupying a dorsal position on the cranium and lying so close together as to make the vertex narrow. Each antenna is set in a socket, the *antennal socket*. The antennal sclerite is wanting but the rim of the antennal socket bears two external inflexions, one antero-mesally and the other antero-laterally, for the articulation of the scape. The base of the antenna is connected to the socket through an elastic membrane, the *antacrium*. Each antenna consists of (i) a basal segment, the scape ; (ii) a small second segment, the pedicel and (iii) a many segmented flagellum or clavola.

The *scape* is broad and strongly built. The *pedicel* is small whose proximal convex surface fits into the distal concave surface of the scape. The *flagellum* consists of thirty-seven sub-segments all of which are not of the same size. The sub-segments of the proximal part are longer while those of the distal part broader and arranged in such a manner as to form a club. The proximal end of each subsegment fits into the distal end of the subsegment preceding it.

The nomenclature of muscles has always presented difficulties to the students of morphology. It is desirable to name a muscle according to its function but unfortunately it is not always possible to ascertain the function of each and every muscle in a dead specimen, more particularly in the thoracic region where a large number of muscles often remain crowded together at a common place. In such cases the function of a muscle becomes often doubtful. Nevertheless, its position is always a certainty. I have, therefore, preferred the line of certainty and have named them according to their position *i.e.*, I have followed a system of positional nomenclature in which the name of a muscle bears both its points of origin and insertion. Wherever possible, the functions of the muscles have been described.

Each antenna is provided with two sets of muscles, extrinsic and intrinsic. The extrinsic muscles are : the *first tentorio-antennal* (1) which arises from the broader

part of the anterior tentorial arm and is inserted on the anterior basal margin of the scape. The *second tentorio-antennal* (2) also arises from the anterior tentorial arm mesad to (1) and is inserted on the basal margin of the scape behind (1). These muscles pull the antenna in a vertical plane. The *third tentorio-antennal* (3) arises from the dorso-lateral flange of the tentorial arm and is inserted on the posterior basal margin of the scape. The *fourth tentorio-antennal* (4) has its origin on the dorsal flange of the tentorial arm and is inserted on the basal margin of the scape behind (3). These muscles pull the antenna down in a vertical plane. The two intrinsic muscles arise on the anterior and posterior basal margins of the scape and are inserted on the base of the pedicel. The one which is inserted on the anterior margin of the pedicel is the *anterior flagellar* (5) and the other, inserted on the posterior margin, is the *posterior flagellar* (6). These muscles move the flagellum.

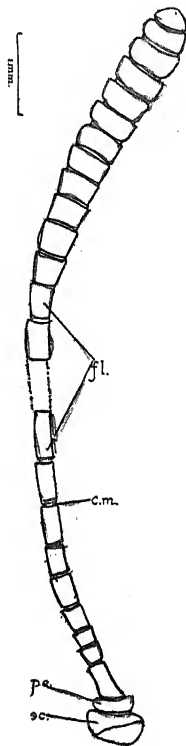


Fig. 3. Antenna with the middle subsegments of the flagellum removed. *c. m.*, connecting membrane; *fl.*, flagellum; *pe.*, pedicel; *sc.*, scape.

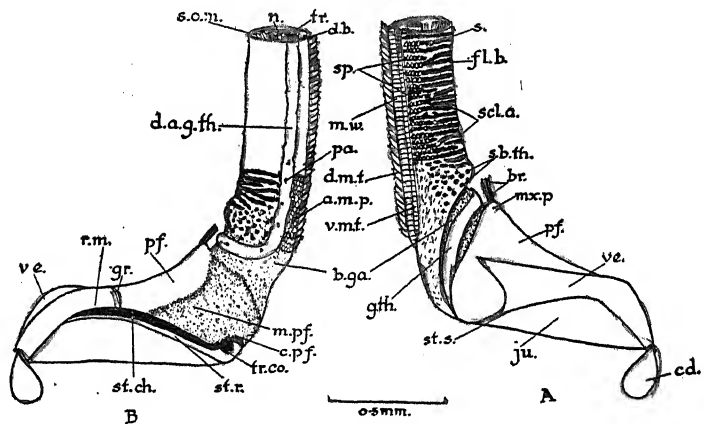


Fig. 4. Left maxilla with only a portion of the galea. A, ventral view; B, dorsal view; *a. m. p.*, area of minute patches; *b. ga.*, basal portion of galea; *br.*, bristles; *c. pf.*, palpifer cut to show tracheal collar; *cd.*, cardo; *d. a. g. th.*, dorsal arm of girdle-like thickening; *d. b.*, dorsal bar; *d. m. t.*, dorsal marginal tooth; *fl. b.*, flexible band; *g. th.*, girdle-like thickening; *gr.*, incomplete groove; *ju.*, juxtastipes; *m. w.*, mesal wall of galea; *m. pf.*, membranous part of palpifer; *mx. p.*, maxillary palp; *n.*, nerve; *pa.*, papilla; *pf.*, palpifer; *r. m.*, rolled margin of palpifer; *s.*, sensillum; *s. b. th.*, spherical basal thickenings; *s. o. m.*, serial oblique muscle; *scl. a.*, sclerotic arcs; *sp.*, spines; *st. ch.*, stipital chamber; *st. r.*, stipital ridge; *st. s.*, stipital sulcus; *tr. co.*, tracheal collar; *tr.*, trachea; *v. m. t.*, ventral marginal tooth; *ve.*, verastipes.

The mouth-parts and their muscles.

The mouth parts are of the sucking type and have, therefore, undergone different degrees of reduction and specialization. They consist of (i) a labrum; (ii) a pair of maxillae and (iii) a labium.

The *labrum* (Fig. 1) is a narrow strongly sclerotized and slightly submarginal area of the epistoma with which it is fused. Snodgrass (1935), Imms (1938), Pradhan

and Aren (1941) have suggested, in their diagrams, the presence of a clypeo-labral suture which is absent in *P. demoleus*. The labrum is produced into a median protuberance on either side of which is present a small club-shaped pilifer. Each pilifer bears small fine bristles. The labral portion of the epistoma is in a close contact with the basal membranous part of the proboscis and the median protuberance closes the roof of the food canal in that region. The ventral wall of the labrum and clypeus, the *clypeo-labral epipharynx*, forms the roof of the cibarial portion of the sucking-pump (vide infra).

The *maxillae* (Fig. 4), though greatly modified, have not lost their typical structure as their various parts can still be distinguished. They lie on the ventral surface of the cranium on either side of the labium. Each maxilla consists of a proximal piece, the *cardo* and a distal piece, the *stipes*—the two being lodged in two fossae on the cranial floor.

The *cardo* is small more or less oblong whose narrow distal end is wedged into a notch in the proximal end of the *stipes*, while the broad proximal end remains in contact with the concave margin of a small hypostomal projection, the *paracolla*.

The *stipes* is more or less a triangular structure. The *stipes* of the two sides diverge from each other towards their proximal ends. Laterally they are supported on the submarginal areas of the subgenae. Each *stipes* is composed of three pieces: (i) an inner piece, the *juxtastipes*, (ii) a middle piece, the *verastipes* and (iii) an outer piece, the *palpifer*. The *juxtastipes* is plate-like whose inner margin is connected to the side of the labium through a membrane while the outer margin is demarcated by a *stipital sulcus* whose distal three-fourth form a ridge, the *stipital ridge*. The distal part of the ridge is broad and forms a collar around the trachea at its entrance into the maxilla. This collar protects the trachea from compression during the movement of the proboscis. The *verastipes* is strongly sclerotized, elongated and channel-like. It is broad distally but narrower and curved proximally. Laterally the *verastipes* is demarcated from the *palpifer* by a furrow. The *palpifer* is the outer piece whose free margin becomes rolled in upon itself so as to enclose a space, the *stipital chamber*. The anterior region of the rolled margin fuses with its own body while its lateral margin touches the stipital ridge. The posterior half of the *palpifer* is demarcated from the anterior half by an incomplete groove visible only in the dorsal view. The dorsal portion of the *palpifer* is membranous and is continuous with the basal membranous portion of the galea; the lateral and ventral parts are less sclerotized while the ventro-mesal part is strongly sclerotized and has a concave dorsal surface to accommodate the stipito-galeal muscle (vide infra). The antero-lateral margin of the *palpifer* bears the rudiment of the palpus with a tuft of bristles while the anterior margin bears an elongated tubular structure, the galea which tapers distally.

The *galeae* of the two sides are in close apposition along their mesal surfaces to form the proboscis which remains coiled beneath the head when not in use. The two galeae (Fig. 5) are held together by means of teeth present on their dorso-mesal and ventro-mesal margins. The dorsal teeth are longer than the ventral ones. The elongated dorsal teeth of each galea are arranged in a single row and are closely placed except towards the tip where they get slightly separated. The teeth of one side remain locked with those of the other side, however they get easily separated in sectioning the proboscis. The ventral teeth are in two rows arising from the same base. The teeth of the lower row are curved and bigger as compared to those of the upper row. The teeth of the two sides are closely interlocked. They fit so closely that no space is left between them. The two galeae are kept in position mostly due to the grip of the ventral teeth.

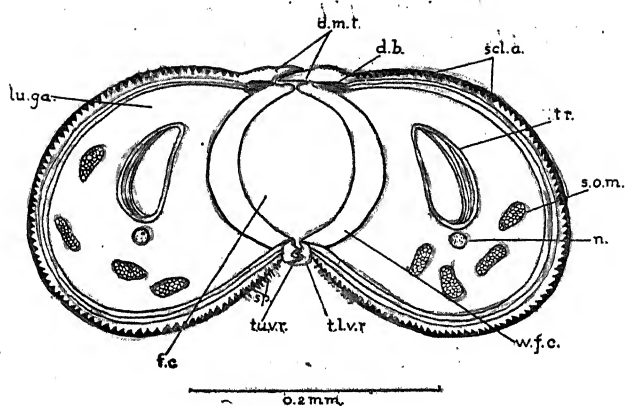


Fig. 5. Cross-section of the proboscis. *d. b.*, dorsal bar; *d. m. t.*, dorsal marginal teeth; *f. c.*, food canal; *lu. ga.*, lumen of galea; *n.*, nerve; *s. o. m.*, serial oblique muscle; *scl. a.*, sclerotic arcs; *sp.*, spines; *t. l. v. r.*, lower tooth of ventral row; *t. u. a. r.*, upper tooth of ventral row; *tr.*, trachea; *w. f. c.*, wall of food canal:

The apposite mesal walls of the two tubular galeae remain pushed in so that each appear somewhat semilunar in a cross-section. By this inpushing a concavity is formed and the concavities of the two galeae together form the food canal of the proboscis. The food canal distal to the labrum is tubular while at the level of the labrum the two galeae separate and start diverging. The overhanging labrum forms the roof of the food canal in that region. Both the outer and the mesal walls of the galea are strengthened by sclerotic arcs alternating with flexible bands. The arcs of the outer wall are composed of small thickenings which are loosely packed towards their dorsal extremities. Due to the coalescence of these thickenings, the arcs appear as beaded. Some arcs are small covering half or less than half of the galeal circumference while some show branching and anastomosis at places. On the surface of some arcs, there are present small unsclerotized spherical areas which probably represent some kind of sinsella (Fig. 4). The ventral portion of each arc bears spines which are more numerous in the proximal portion of the galea. They gradually diminish in size and number distalwards, finally disappearing from the distal one-fourth of the galea. At the dorsal junction of the mesal and outer walls of the galea lies a solid bar, the *dorsal bar* which, according to Estham and Eassa (1955), gives the proboscis the ability to coil when at rest. It originates from the proximal end of the coilable part of the galea and extends upto the tip towards which it gets relatively thinner. The outer wall next to the dorsal bar presents a band of minute patches which also extends from the proximal end to the tip of the galea (Fig. 7). The sclerotic arcs of the mesal inpushed wall of the galea are placed very closely and cannot be easily detected. They do not show any beaded appearance. The basal portion of the galea which lies beneath and behind the labrum is membranous and uncoilable. It bears minute spines on its surface and has a girdle-like thickening around it. The ventral arm of the thickening is fused with the antero-mesal border of the stipes and the dorsal arm runs along the galea between the extremities of the sclerotic arcs and the area of the minute patches. Distributed on the surface of the long dorsal arm of the girdle-like thickening, are small papillae which may be sensory in function. Immediately distal to the girdle, the galea bears small chitinized sperical patches. These patches also have minute spines and

are unarranged in the begining but gradually get arranged in the form of arcs which constitute the beaded sclerotic arcs of the outer wall of the galea.

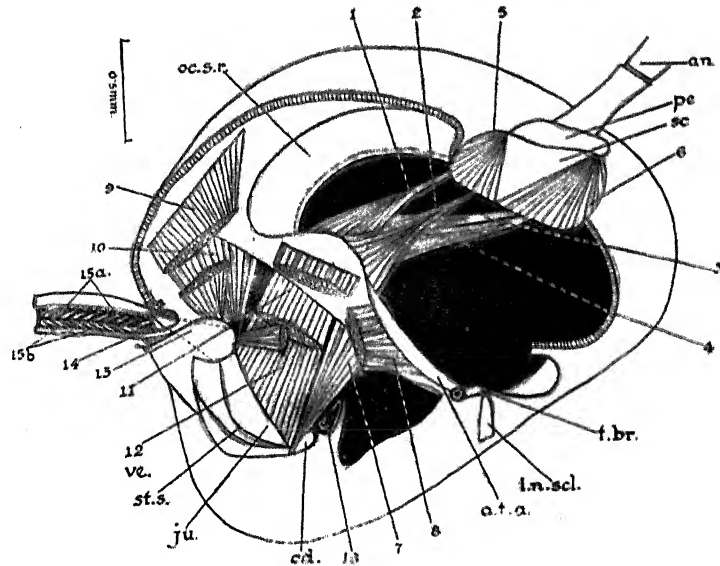


Fig. 6. Right half of the vertical-median section of the head (sucking-pump with muscles removed, semidiagrammatic). *a. t. a.*, anterior tentorial arm; *an.*, antenna; *cd.*, cardo; *ju.*, juxtastipes; *l. n. scl.*, lateral neck sclerite; *oc. s. r.*, oculo-subantennal ridge; *pe.*, pedicel; *sc.*, scape; *st. s.*, stipital sulcus; *t. br.*, tentorial bridge; *ve.*, verastipes; 1, first tentorio-antennal muscle; 2, second tentorio-antennal muscle; 3, third tentorio-antennal muscle; 4, fourth tentorio-antennal muscle; 5, anterior flagellar muscle; 6, posterior flagellar muscle; 7, tentorio-cardinal muscle; 8, first tentorio-stipital muscle; 9, cranio-stipital muscle; 10, geno-stipital muscle; 11, second tentorio-stipital muscle; 12, tentorio-juxtastipital muscle; 13, stipito-galeal muscle; 14, intra-galeal muscle; 15a, dorsal serial oblique muscles of galea; 15b, ventral serial oblique muscles of galea; 16, intra-labial muscle.

There are two sets of maxillary muscles (Fig. 6 and 7), extrinsic and intrinsic. The extrinsic muscles are: the *tentorio-cardinal* (7) which arises from the posterior part of the anterior tentorial arm and is inserted on the distal end of the cardo. The *first tentorio-stipital* (8) originates posteriorly from the mesal surface of the anterior tentorial arm and is inserted on the distal end of the stipital ridge. The *cranio-stipital* (9) originates from the fronto-clypeal area and is inserted on the stipital ridge behind (8). The *geno-stipital* (10) has its origin from the gena and is inserted on the proximal part of the stipital ridge. The *second tentorio-stipital* (11) originates on the ventral surface of the dorso-lateral flange of the tentorial arm and is inserted on the stipital ridge between (9) and 10. The *tentorio-juxtastipital* (12) arises from the broad mesal surface of the anterior tentorial arm and is inserted on the juxtastipes.

The intrinsic muscles are: the *stipito-galeal* (13) which originates on the concave surface of the antero-mesal part of the palpifer and is inserted on the girdle-like thickening at the base of the galea. This muscle draws the proboscis backwards to bring the food canal in line with the functional mouth. The *intra-galeal* (14) is a small muscle originating on the ventro-mesal margin of the proximal end of the coilable part of the galea and is inserted on the girdle-like thickening anterior to (13). The *serial oblique muscles of galea* (15a & 15b) are small oblique muscles arranged in two series—a dorsal and a ventral—throughout the coilable part of each galea.

The muscles of each series originate in a broad base from the middle region of the outer wall of the galea. From this origin, the muscles of the dorsal series taper dorso-posteriorly to a single point insertion on the sclerotic arc and those of the ventral series taper ventro-posteriorly to a similar insertion. Thus, the muscles get obliquely disposed. The muscles in the proximal portion of the galea are longer and more oblique but as the distal end is reached they become shorter and get more or less transversely arranged. The function of these muscles, as attributed by Pradhan and Aren (1941), is to bring about the uncoiling of the proboscis.

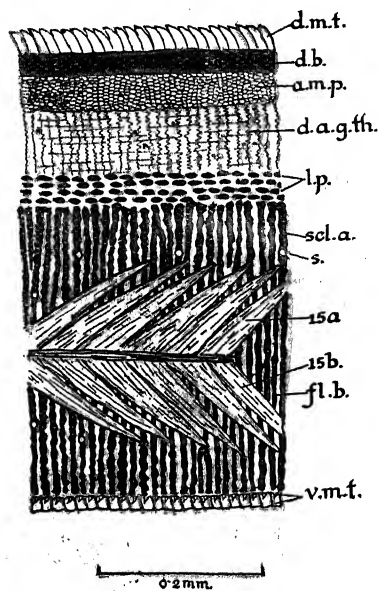


Fig. 7. Inner view of a portion of the galea stretched. *a. m. p.* area of minute patches; *d. b.*, dorsal bar; *d. a. g. th.*, dorsal arm of girdle-like thickening; *d. m. t.*, dorsal marginal tooth; *fl. b.*, flexible band; *l. p.*, loose patches; *s.*, sensillum; *scl. a.*, sclerotic arc; 15a and 15b, dorsal and ventral serial oblique muscles of galea respectively; *v. m. t.*, ventral marginal tooth.

The *labium* (Fig. 2) is an undivided membranous area between the two maxillae closing the cranium on the ventral aspect. The anterior margin of the labium is fused with the anterior margin of the hypopharynx and at the junction of the two opens the common salivary duct. Its floor at the opening is sclerotized. The posterior margin of the labium is slightly sclerotized and fused with the hypostomal bridge along the *labio-hypostomal suture*. Each postero-lateral side of the labium bears a labial palp which has three segments the proximal segment being the longest and the distalmost the shortest. The first two segments are thin walled while the third is slightly sclerotized. The ventral and the lateral surfaces of the palpi are covered with bristles which give them a bushy appearance.

The labium has only one pair (Fig. 6) of small muscles, the *intra labial muscles* (16). Each muscle originates from the sclerotized part of the labial base and is inserted dorsally on the labial palp. These muscles act as the elevators of the palpi.

Morphology of the sucking-pump and its muscles.

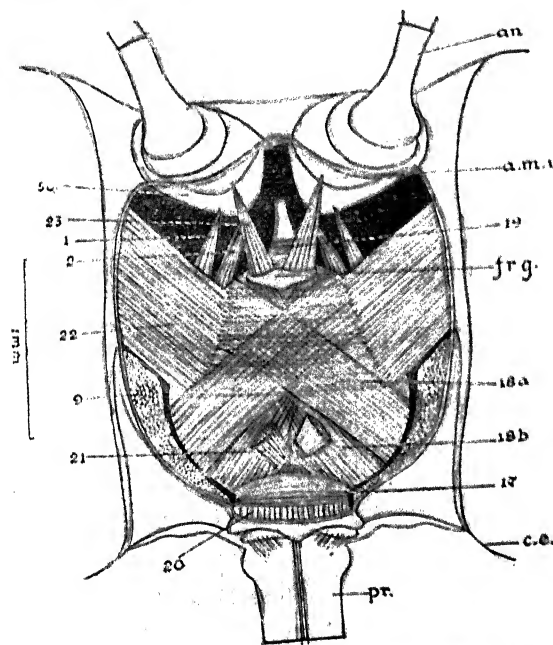


Fig. 8. Head dissected from the facial aspect. *a. m. i.*, antero-mesal inflection of the rim of antennal socket; *an.*, antenna; *c. e.*, compound eye; *fr. g.*, frontal ganglion; with connectives; *pr.*, proboscis; *sc.*, scape; 1 and 2, tentorio-antennal muscles; 9, cranio-stipital muscle; 17, cibarial compressor; 18a, dorsal sheath of buccal compressor; 18b, ventral sheath of buccal compressor; 19, pharynx; 20, anterior clypeo-cibarial muscle; 21, posterior clypeo cibarial muscle; 22, subantenna-buccal muscle; 23, fronto-pharyngeal muscle.

The sucking-pump (Fig. 8) is a complex organ by which the butterfly varies the air pressure, and creates a sucking force. The juice from the nectaries of the flowers is sucked into the food canal of the proboscis, whence into the pump itself. It is a globular capsule opening in front through a narrow slit-like aperture, the *functional mouth* into the food canal of the proboscis and behind by a small aperture into the oesophagus. Due to its large size, the anterior tentorial arms become slightly diverged anterior wards to accommodate the pump. The roof of the pump is flexible and membranous and sags into the cavity of the pump due to the weight of the overlying muscles. Its floor is strongly sclerotized and is in the form of a shallow bowl. The anterior margin of the floor of the pump is fused with the anterior margin of the labium, the common salivary duct opening, in the middle line, at the junction of the two margins. On each side of the ventral surface of the floor of the pump, there is present a ridge-like suspensorial sclerite which connects the floor to the angles of the functional mouth. The suspensorial sclerite of the two sides posteriorly run towards the middle line. The sucking-pump tapers to merge into the oesophagus posteriorly.

The muscles the sucking-pump (Figs. 8 and 9) can be studied under two groups: intrinsic and extrinsic. The intrinsic muscles act as the compressors of the sucking-pump while the extrinsic ones act as the dilators. Amongst the intrinsic muscles, the *cibarial compressor* (17) lines between the anterior and posterior clypeo-

cibarial muscles. The fibres of this muscle run transversely over the roof of the sucking-pump from the suspensorial sclerite of one side to that of the other side. On contraction, it closes the entrance from the proboscis. The *buccal compressor* (18) form two sheaths, a ventral and a dorsal, on the roof of the pump behind the cibarial compressor. The fibres of the ventral sheath originate anteriorly on the suspensorial sclerites and pass upwards and backwards on the dorsal surface of the pump, the fibres of one side crossing those of the other side. While crossing, the fibres get interwoven. Posteriorly the fibres run downwards to be inserted on the ventral wall of the pump. The muscle fibres of the dorsal sheath originate on the suspensorial sclerite of one side, pass up over the roof of the pump to the suspensorial sclerite of the other side. The fibres of this sheath are of two types: those of one type pass transversely over the roof and those of other type make a cross, the fibres of the two types become interwoven. The *pharyngeal compressor* (19) surround the pharynx behind the frontal ganglion. On contraction, it closes the opening of the sucking-pump into the oesophagus.

The extrinsic muscles are: the unpaired *anterior clypeo-cibarial* (20) which originates on the clypeus and is inserted on the anterior part of the roof of the sucking-pump. The *posterior clypeo-cibarial* (21) are paired. Each muscle arises on the clypeal area and is inserted on the sucking-pump behind (17). The *subantenna-buccals* (22) are paired and very thick muscles. Each muscle originates on the inner surface of the oculo-subantennal ridge, runs obliquely to get insertion on the roof of the buccal region. The fibres of this muscle have to penetrate through the sheaths of the buccal compressor to reach the surface of the roof. The *fronto-pharyngeals* (23) are also paired, each originating on the inflected part of frons to be inserted on the roof of the pump behind the frontal ganglion. Eastham and Eassa (1955) mention the origin of this muscle (which in their case is unpaired) on the clypeus. This is not in agreement with the now conclusively proved fact that the clypeus in adult *Lepidoptera* does not extend so far behind and that the origin of the pharyngeal dilator is on the frons.

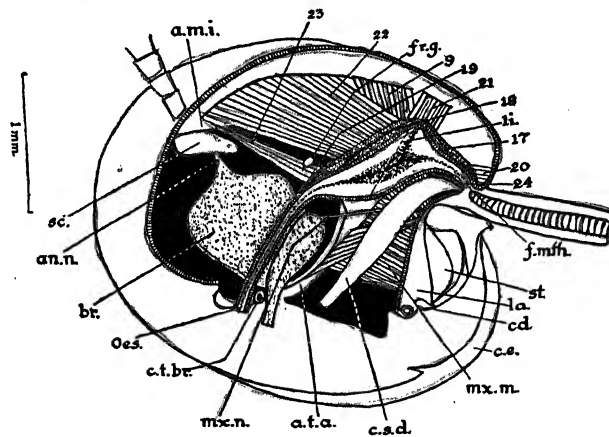


Fig. 9. Left half of the vertical-median section of the head. *a. m. i.*, antero-mesal inflection of the rim of antennal socket; *a. t. a.*, anterior tentorial arm; *an. n.*, antennal nerve; *br.*, brain; *c. e.*, compound eye; *c. s. d.*, common salivary duct; *c. t. br.*, tentorial bridge (cut); *cd.*, cardo; *f. mth.*, functional mouth; *fr. g.*, frontal ganglion; *hyp.*, hypopharynx; *la.*, labium; *li.*, line demarcating the cibarial from the stomodaeal part; *mx. m.*, maxillary muscles; *mx. n.*, maxillary nerve; *oes.*, oesophagus; *sc.*, scape; *st.*, stipes; 9, cranio-stipital muscle; 17, cibarial compressor; 18, buccal compressor; 19, pharyngeal compressor; 20, anterior clypeo-cibarial muscle; 21, posterior clypeo-cibarial muscle; 22, subantenna-buccal muscle; 23, fronto-pharyngeal muscle; 24, suspensorio-salivary muscle.

The exact morphology of the sucking-pump (Fig. 9) of butterflies has been a subject of great controversy. Snodgrass (1935) pointed out that the lepidopterous sucking-pump includes both the cibarial and stomodaeal parts, Schmitt (1938) has conclusively proved the same. But the extent to which the stomodaeum and the cibarium contribute towards the formation of the sucking-pump has so far remained unaccounted. Short (1951) maintains that it is not possible to ascertain their precise contribution. The present studies, however, reveal that the sucking-pump can be divided into two regions: (i) an anterior pre-oral or cibarial part and (ii) a posterior stomodaeal part including the buccal cavity and the pharynx. In the generalized insect the cibarium is formed by the clypeo-labral epipharynx dorsally and the hypopharynx ventrally. Similarly, here also, the roof of the anterior part of the sucking-pump is formed by the clypeo-labral epipharynx and the floor by the hypopharynx. There is no doubt the morphology of the roof as it is definitely the ventral wall of the clypeo-labrum. Regarding the floor there are three evidences to show that it is formed by the hypopharynx: (i) the opening of the common salivary duct is situated at the junction of the ventral wall of the pump and the labium, (ii) the presence of a suspensorial sclerite on each side of the floor of the pump and (iii) the presence of a pair of *suspensorio-salivary muscles* (24) which have their origin on the suspensorial sclerites and insertion dorsally on the anterior end of the common salivary duct. The suspensorial sclerites also determine the minimum posterior extent of the floor of the cibarium.

The posterior extent of the roof of the cibarium can be ascertained by the positions of the dilator muscles which, as already mentioned, are two: the anterior clypeo-cibarial and the posterior clypeo-cibarials. As these muscles take their origin on the clypeus, they should either be buccal dilators or cibarial dilators (Snodgrass, 1935). Since the buccal dilators have shifted their origin in this case, it follows that (i) the above two muscles can only be the cibarial dilators; (ii) the portion of the sucking-pump on which they are inserted should, therefore, be the cibarium and that (iii) the posterior clypeo-cibarial muscles mark the posterior limit of the roof of the cibarium. Having ascertained the extent of the roof and the floor of the cibarium, it becomes evident that the roof is shorter than the floor. A line joining the posterior ends of the roof and the floor will demarcate the cibarium from the stomodaeum. Further, the frontal ganglion lies on the dorsal wall of the stomodaeum between the buccal cavity and the pharynx. Therefore, the portion of the sucking-pump between the ganglion and the posterior clypeo-cibarial muscles should be regarded as the buccal region and thus the subantenna-buccal muscles will correspond to the buccal dilators of the generalized insect. The relatively small portion of the sucking-pump behind the frontal ganglion is undoubtedly the pharynx provided with a pair of fronto-pharyngeal muscles which act as the pharyngeal dilators. These muscles are closely encircled by the frontal ganglion connectives.

Endoskeleton of the head.

The *tentorium* (Fig. 10) is π -shaped consisting of (i) a pair of anterior tentorial arms and (ii) a pair of posterior tentorial arms.

The *anterior tentorial arms* are elongated somewhat laterally compressed and broader above their bases. They diverge anteriorly to accommodate the huge sucking-pump in between. The base of each arm fuses with the subantennal ridge of its own side. There are two flanges on the broader part of the arm, one dorsal and the other dorso-lateral. The anterior tentorial pits are situated on the facial aspect of the cranium at the dorsal ends of the subgenal sutures and mark the places of invagination of the anterior tentorial arms.

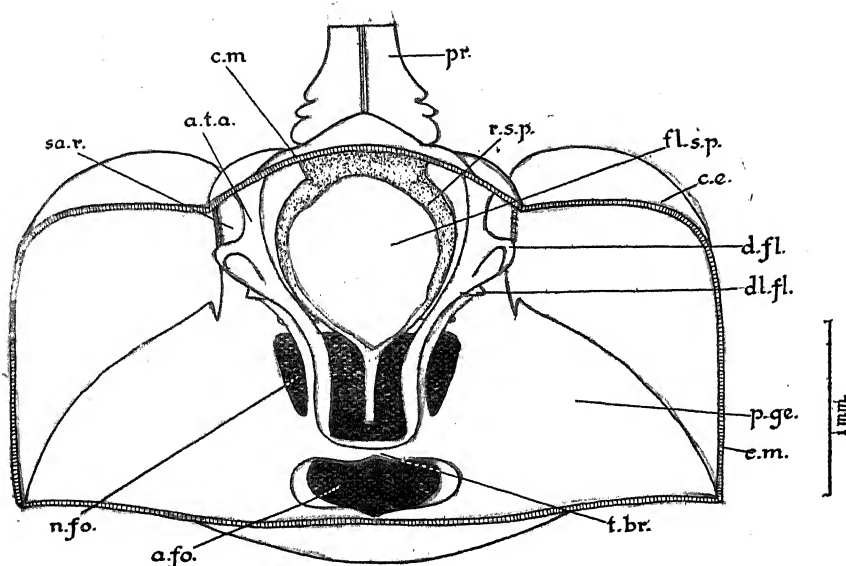


Fig. 10. Inner view of the cranium as seen after cutting away its dorsal wall. *a. f. o.*, alafortamen; *a. t. a.*, anterior tentorial arm; *c. e.*, compound eye; *c. m.*, cut margins; *d. fl.*, dorsal flange; *dl. fl.*, dorsolateral flange; *fl. s. p.*, floor of sucking-pump; *n. fo.*, neuro-foramen; *p. ge.*, postgena; *pr.*, proboscis; *r. s. p.*, roof of sucking-pump (cut); *sa. r.*, subantennal ridge; *t. br.*, tentorial bridge.

The *posterior tentorial arms* of the two sides are fused to form a hollow tentorial bridge which divides the occipital foramen into an upper *alafortamen* through which passes the alimentary canal and a lower *neuroforamen* giving passage to the ventral nerve cord and the salivary ducts. The posterior tentorial pits are prominent and each of them is situated on the basal sides of the alafortamen at the ends of the postoccipital sulcus.

SUMMARY

1. The head has been described in detail; it is hypognathous and most of its sclerites have fused.
2. The face is formed by a single plate, the epistoma which is composed of fused labrum, clypeus and frons whose limits can still be ascertained.
3. The occipital foramen is elongated and is divisible into an alafortamen and a neuroforamen by the tentorial bridge.
4. The mouth-parts are greatly reduced except the maxillae which have become greatly modified and whose galeae elongate to form the proboscis.
5. The sucking-pump is a huge structure formed of the cibarium, buccal region and the pharynx.
6. The antenna has four extrinsic and two intrinsic muscles; the maxilla has six extrinsic and three intrinsic muscles; the sucking-pump bears a paired and an unpaired cibarial dilators, a paired buccal dilators, a paired pharyngeal dilators and three compressor muscles.
7. The tentorium is π -shaped and the tentorial pits are well marked.

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A NEW SPECIES OF PEGOSOMUM, AN ECHINOSTOME (TREMATODA) FROM CATTLE EGRETT

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(Received on 13th April 1957)

This paper describes a new species of the genus *Pegosomum* Rätz (1903) of which no species has so far been reported from India, the five species already known are from other countries. This parasite was collected by the author from a cattle egret, *Bulbulcus ibis coromandus* at the Zoological Laboratory of the University of Allahabad in 1950, at different times of the year. Only fifteen out of fifty cattle egrets examined from the suburbs of Allahabad were found to be infected with this parasite, the percentage of infection thus being about 30%. The worms were obtained from the bile passages in the liver in which they lay firmly attached to their walls. The bile passages had developed thick walls, presented a cyst like appearance and contained 1-5 of these parasites.

Pegosomum egretti n. sp.

In the living condition the worm is brown in colour and shows only slight movements of its body. Its body is dorsoventrally flattened, tapering towards both the ends.

It measures $6.67 - 8.7 \times 2.6 - 3.25$ mm. in size, the maximum breadth being in the region just anterior to acetabulum. The body tapers more sharply from the level of maximum breadth towards the anterior end. The cephalic collar as usual in the genus is very poorly developed measuring 0.338 mm. across. It is armed with dorsally uninterrupted 25 spines arranged alternately in double rows. The ventral corner group on each side consists of four larger spines which are bluntly pointed and measure $0.05 - 0.06 \times 0.018 - 0.024$ mm. in size. The dorsal spines alternating in the two rows are smaller measuring $0.021 - 0.036 \times 0.12 - 0.15$ mm. The entire surface of the body is covered over by small backwardly directed cutaneous spines which are smaller and much more closely set in the preacetabular region (0.018×0.006 mm. in size) than in postacetabular region (0.031×0.009 mm.)

The oral sucker is terminal and almost spherical. It is very weakly developed being devoid of musculature, measuring 0.15 mm. across. In most of the whole mounts the oral sucker could not be seen, because the pharynx had projected anteriorly outside through the inconspicuous oral sucker. Thus the oral sucker though considerably reduced is definitely present. The pre-equatorial ventral sucker is spherical and situated at a distance of 2.63 mm. from the anterior end and at 0.65 - 0.97 mm. distance, from the intestinal bifurcation. It is well developed, and strongly muscular measuring 0.78 - 0.93 mm. across.

The body wall consists, on the outer side of thick structureless cuticle reinforced by spines. In a transverse section, the spines in the cuticle are seen to be studded at unequal distances. Inside the outicle the body wall has three layers of muscles

which constitute its major portion. The outer most is the circular layer of muscle fibres. Internal to this is the layer of longitudinal muscle fibres which forms the middle layer of muscles, the muscle being distinctly grouped into compact bundles. The inner most layer of oblique muscle fibres forms a coat diagonally traversing muscle fibres lying in the parenchyma. Besides the three zones of muscles, there are found scattered glandular patches.

The pharynx is a prominent structure at the anterior end showing variations in its position, shape and size depending upon its state of contraction and projection anteriorly through the oral sucker. In its contracted condition it measures 0.21×0.13 mm. but when fully extended it has 0.3×0.18 mm. in size. The pharynx is followed by the long oesophagus which is broader than the pharynx. The oesophagus, $1.36 \times 0.09 - 22$ mm. in size bifurcates into two widely separated intestinal caeca at a distance of 2 mm. from the anterior end. The intestinal caeca following a somewhat wavy course, reach posteriorly up to the hinder end. The caeca, $5.67 - 7.7$ mm. long, become gradually broader in the post testicular region and attain the maximum breadth of 0.41 mm. They also come quite close towards one another in the post testicular region where they are separated by the maximum distance of 0.13 mm. only.

The testes are post equatorial and post overial, tandem and dissimilar. The anterior testis is boat shaped measuring $0.91 - 1.43 \times 1.56 - 2.34$ mm. The posterior testis is more or less wedge shaped, with somewhat irregular anterior face. In pressed specimens it may appear rounded to oval in shape measuring $1.1 - 1.56 \times 1.49 - 1.88$ mm. in size. The testicular membrane is drawn out to form the vasa efferentia which immediately after entering the cirrus sac unite to form the vas deferens. The cirrus sac, 0.612×0.18 mm. in size, mostly situated in front of the acetabulum, slightly curves round on the left side extending posteriorly for about one fourth of the length of the latter. The thin walled vesicula seminalis which lies in the basal part of the cirrus sac is constricted and filled with sperms. It is connected with the bulbous pars prostatica by a narrow neck. The cirrus is narrower than the pars prostatica and has very thick muscular walls. It has often been found protruded for a considerable length and in the living specimen the everted cirrus is quite prominent even to the naked eye. Between the walls of the cirrus sac and ductus ejaculatorius lie many prostate gland cells which may also extend backwards to surround even the vesicula seminalis. The male genital opening lies in the midventral line between the acetabulum and the intestinal bifurcation.

The ovary is small and lies asymmetrically to the right side between the ventral sucker and the anterior testis. It is slightly lobed and roughly pear shaped measuring $0.45 - 0.45 \times 0.27 - 0.36$ mm. with the long axis transversely situated and the apex pointing towards the mid ventral line. From it the ova are forced down by muscular oviduct to the ootype. The seminal receptacle is absent. The ootype surrounded by the shell gland mass lies posterolateral to the ovary in the central region between the acetabulum and the anterior testis. The Laurers' canal is more or less well developed having muscular walls. It takes a sinuous course in the region of the shell gland mass to open to the exterior near the mid dorsal line. The uterus arises from the ootype just where the vitelline reservoir opens into it. The uterine loops which are not numerous mainly lie in the region between the acetabulum and anterior testis mostly in front of the ovary. The uterus terminally continues into the metraterm after ascending to the left side of the acetabulum. The metraterm surrounded by a few gland cells is situated to the left side of the cirrus sac and opens to the exterior by a separate female opening situated close to the male open-

ing. The vitellaria are arranged somewhat in bunches composed of small follicles of 0.03 - 0.09 mm. size. They extend from the middle of oesophagus upto the anterior margin of the posterior testis. Anteriorly the vitellaria unite in the median plane, but they lie quite separately behind the level of oesophageal bifurcation. The ova are oval, yellow and thin shelled measuring 0.09 - 0.126 \times 0.03 - 0.09 mm. in size.

The excretory pore lies at the posterior end of the body. The excretory bladder is Y shaped with the main stem dividing into two branches just behind the posterior testis.

Host—*Bulbulcus ibis coromandus*, the cattle egret.

Location—Liver.

Locality—Allahabad, U. P.

Discussion—Of the five species *P asperum* (Wright, 1879) Rätz, 1903, *P. saginatum* (Rätz, 1898) Rätz, 1903, *P. spiniferum* Rätz, 1903 *P. bulbulcum*, Tubangui and Masilungari, 1935 and *P. Skrjabium*, Skrjalin known so far, the new species shows resemblance most closely to *P. bulbulcum* in the extension of its vitellaria which do not extend behind the testes. In this feature these two species stand apart from the other species of the genus. *P. egretti* n. sp. differs from *P. bulbulcum* in the number of its collar spines and their arrangement in two alternating rows. It is further distinguished from the Philippine species by its larger body, and larger size of the posterior testis, in possessing separate male and female ganital openings and in the anterior extent of vitellaria upto the middle of oesophagus and not up to the pharynx. It may be mentioned that in the account of *P. bulbulcum* no mention has been made of the Laurers' canal which is quite well developed in the new species.

ACKNOWLEDGEMENT

I am glad to express my grateful appreciation to Dr. H. R. Mehra under whose guidance this study was completed. I am also indebted to the Scientific Research committee of the Uttar Pradesh Government for granting a Research Assistantship for this work under Professor H. R. Mehra.

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EXPLANATION OF PLATE

All figures were made with the aid of camera lucida.

ABBREVIATIONS

Acet.	Acetabulum
Cis.	Cirrus sac
Ci.	Cirrus
C. S.	Cephalic Spines
E. P.	Ecretory pore
F. G. O.	Female genital opening
G. O.	Genital opening
H. C.	Cephalic Collar
I. C.	Intestinal Caeca
Met.	Metraterm
O.	Ova
OES.	Oesophagus
Os.	Oral Sucker
OV.	Ovary
Ph.	Pharynx
Sh lg.	Shellgland
T 1.	Testis anterior
T 2.	Testis posterior
Vit.	Vitellaria
Vit P.	Vitelline Reservoir
Ves. sem.	Vesicula Seminalis

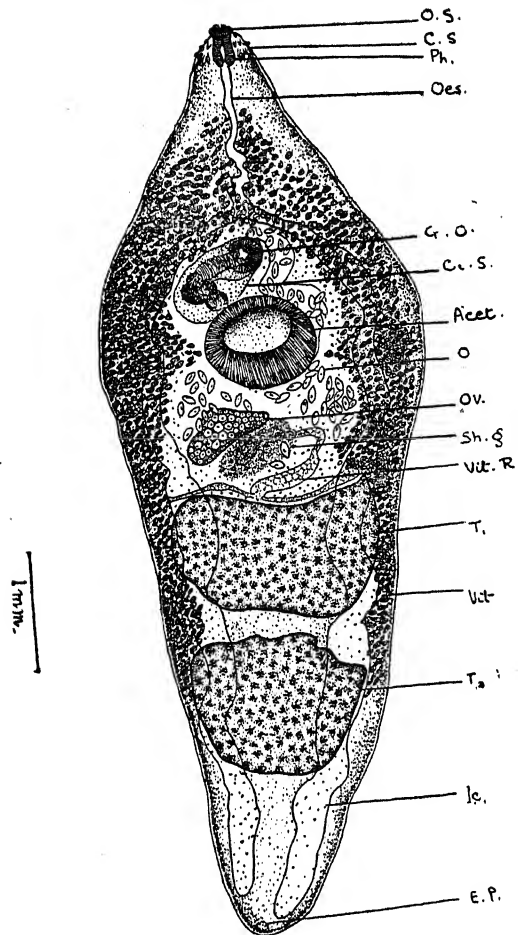


Fig 1. *Pegosomum egretti*, entire mount

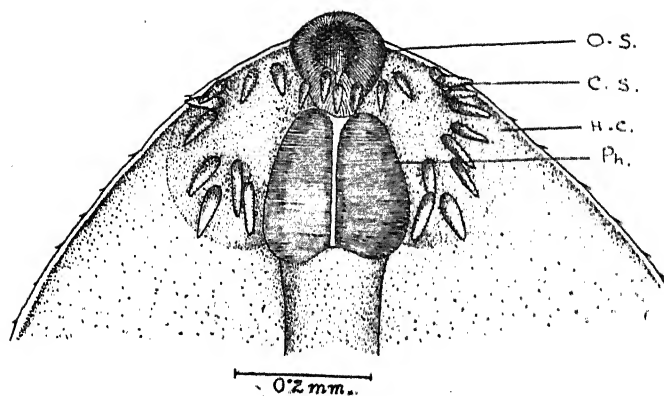


Fig 2. *P. egretti*, Cephalic region.

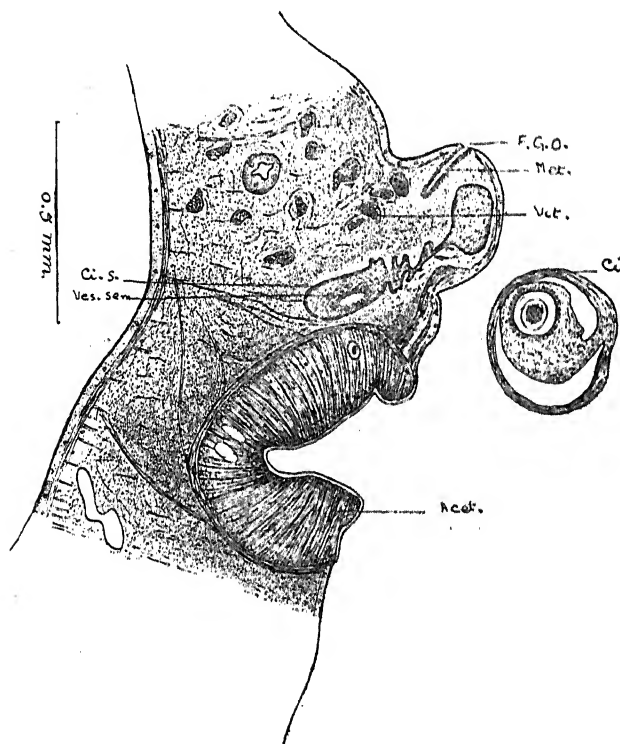


Fig 3 *P. egretti*, V. L. S. showing everted cirrus, cirrus sac, metatrachea and female genital opening.

POPULATION OF CATERPILLARS OF *CHILO ZONELLUS* SWINHOE IN *JUAR (SORGHUM VULGARE)* AND *MAIZE (ZEA MAYS)**

By

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Received on 4th October 1956

INTRODUCTION

In developing chemical, mechanical and biological methods for controlling insects in the field, it is necessary to determine the density of the larval population from time to time to obtain information on the effectiveness of the different treatments. To count all the larvae by cutting stem is not practicable, when the area is large, because of the enormous amount of labour involved. Moreover, it is not satisfactory because many larvae are killed or injured mechanically during the operation. It was, therefore, necessary to develop a method of examining small portions of a given area by which larval populations could be estimated without disturbing the entire crop.

TECHNIQUE

The technique followed in the selection of plants for observation was random stratified sampling. The unit area for each reading was an equilateral triangular plot of the side of 33' (1/92.5 acres). Ten percent plants of this unit area were selected for observation. The leaves, the leaf sheaths, the leaf buds and the stems of the selected plants were examined for the larvae. The total number of larvae and their average per plant were calculated. Special attention was given to the top shoot where a large number of the larvae especially in their early stages were found.

The population per acre in both the crops was calculated and graphically represented. (fig 1 and 2).

*The work formed a part of thesis submitted in lieu of a paper of the M. Sc. (Ag.) degree in Agricultural Zoology-Entomology of Agra University.

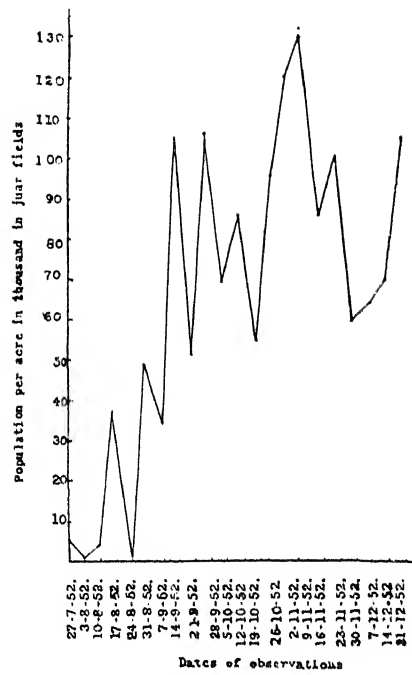


Fig 1

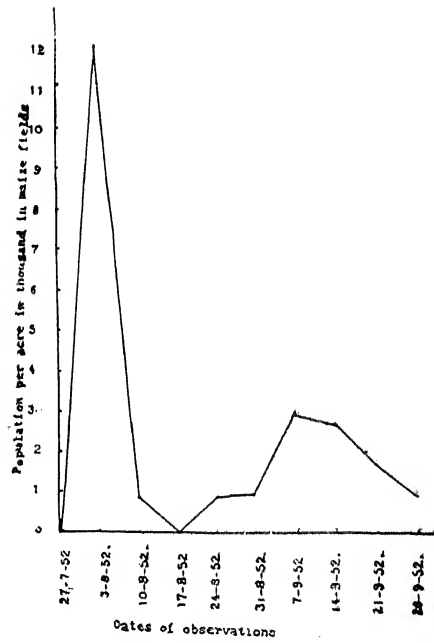


Fig. 2

Experimental findings

TABLE No. 1

Showing the population of the caterpillars in juar.

Serial No.	Observation date	Field No.	No. of plants observed in triangular plot	No. of larvae found	No. of larvae per plant	Exact No. of plants in triangular plot	Approx. No. of plants per acre	Population per acre	Max. No. of larvae found in a plant	Remark
1	2	3	4	5	6	7	8	9	10	11
1	27-7-1952	13/1	59	6	0.12	524	48470	5816	1	Fedder Crop.
2	3-8-1952	14/1	143	1	0.01	1437	132923	1329	1	"
3	10-8-1952	15/1	118	5	0.04	1088	100640	4026	2	"
4	17-8-1952	9/1A	127	40	0.32	1274	117845	37710	3	"
5	24-8-1952	17/1	16	2	0.13	158	14615	1900	1	"
6	31-8-1952	7/2	21	53	2.52	210	19425	48951	8	Grain crop of juar and arhar mixed, sown alternately in 2 rows of juar with one row of arhar each 2, 6' apart.
7	7-9-952	4/1	44	38	0.84	444	41070	34499	15	"
8	14-9-1952	15/2	62	112	1.81	624	57720	104473	6	"
9	21-9-1952	4/2	53	55	1.04	534	49395	51371	5	"
10	28-9-1952	9/13	103	105	1.02	1113	102953	105012	7	Fedder crop.
11	5-10-1952	17/3	20	73	3.65	204	18870	68876	11	Grain crop as above.
12	12-10-1952	17/4	20	94	4.70	197	18232	85648	8	"
13	19-10-1952	17/5	16	58	3.63	163	15078	54733	9	"
14	26-10-1952	18/1	17	103	6.06	169	15633	94736	4	"
15	2-11-1952	18/2	15	132	8.80	148	13690	120472	18	"
16	9-11-1952	18/3	16	141	8.81	159	14708	129573	17	"
17	16-11-1952	18/4	16	90	5.63	164	15170	85407	10	"
18	23-11-1952	17/1	15	106	7.07	153	14152	100054	16	"
19	30-11-1952	17/2	17	66	3.88	166	15355	59577	9	"
20	7-12-1952	18/1	17	68	4.00	170	15725	62900	10	"
21	14-12-1952	17/3	15	73	4.87	154	14245	69373	9	"
22	21-12-1952	17/4	16	110	6.88	164	15170	104370	15	"
Total				...	75.83	Total ...		1430806		
Average				...	3.45	Average...		65036.63		

TABLE No. 2

Showing population of the caterpillars in maize.

Serial No.	Observation date	Field No.	No. of plants observed in triangular plot	No. of larvae found	No. of larvae per plant	Exact No. of plants in triangular plot	Approx No. of plants per acre	Population per acre	Max. No. of larvae found in a plant
1	2	3	4	5	6	7	8	9	10
1	27-7-52	...	16	0	0.00	164	15170	0	0
2	3-8-52	...	14	11	0.79	143	13228	12004	4
3	10-8-52	...	16	1	0.06	155	14430	866	1
4	17-8-52	...	13	0	0.00	134	12345	0	0
5	24-8-52	...	14	1	0.07	137	12673	887	1
6	31-8-52	...	17	1	0.06	168	15540	932	1
7	7-9-52	...	17	3	0.18	174	16095	2897	1
8	14-9-52	...	16	3	0.19	156	14430	2741	2
9	21-9-52	...	18	2	0.11	176	16280	1791	1
10	28-9-52	...	17	1	0.06	168	15540	932	1
Total ...						Total ...	145781	23050	
Average ...						Average ...	14578 ¹	2305	

DISCUSSION

The average number of caterpillars of *Chilo zonellus* S. per plant from July to December is about 4 (Table 1) in *juar* and negligible in *maize* (Table 2), whereas the maximum number of larvae per plant found in nature was 18 and 4 respectively. According to Pruthi and Pradhan (1945) the population of caterpillars per acre is more reliable than the population per plant because in the latter both the number of plants as well as the number of larvae per plant are variable, but in the former the acre is a fixed scale and only population is variable. Therefore, the weekly population per acre has been calculated.

The average population per acre in *juar* for fodder and in *juar* for grain is 30778 and 75112 caterpillars respectively. The great difference is because *juar* for fodder remains in the field upto the end of September only, while that for grain remains in the field upto the end of December i. e. the past takes more time for multiplication in the fields of grain crop than in that of fodder crop.

The average population of larvae per acre in *juar* on the whole is 65036.63 ± 263.8 (appendix 1 for S. E.) and in *maize* 2305 ± 1702 . The population study of the larvae in these two crops has not been so far done in India. Harukawa, et. al. (1955) gave the average for 6 years comprising 1928 to 1933 as 3000 - 4000 larvae of *Chilo simplex* Butl. per tan (= $\frac{1}{4}$ acre) for the first generation in *rice*, but in the outbreak of 1932 these were as many as 13000 larvae per tan and more than 200000 larvae per tan for second generation. According to Hirose (1935) 90 larvae were present on the average in 35 square feet of *rice* field. Liu (1933) studied the effect of rotations on the population and found that the numbers of the larvae of the above species per 1000 *rice* stubble clusters were 64.83 in fields growing green manure and 61.35 in follow fields and 5 in *wheat* fields.

According to Burt (1916) the population in *juar* of *Chilo simplex* Burt. was large at Kanpur in August and September. But the following table shows that the maximum population in *juar* was in November and in *maize* it was maximum in August.

TABLE III

Showing monthly average population of larvae per acre in *juar* and *maize*

Sr. No.	Month	Population per acre	
		<i>juar</i>	<i>maize</i>
1	July	5816	Nil
2	August	18783	8938
3	September	73839	2090
4	October	65998	×
5	November	99017	×
6	December	78881	×

Weekly averages for naturally prevailing temperature and relative humidities corresponding to the weekly population were calculated and given in appendix 2. The correlation average temperatures and weekly population given as $+ \cdot 4630$ (appendix 1) is significant at 5 % level of significance. This indicates that there is moderate positive correlation between temperature and population. Similarly $+ \cdot 6748$ (appendix 1), the correlation between average relative humidities and weekly populations is highly significant even at 10 % level of significance. This shows that there is high positive correlation between relative humidities and populations. Thus it is concluded that as the temperature or R. H. increases or decreases there is corresponding increase or decrease in the population. The partial correlation between average temperature and corresponding population when relative humidity is held constant, is $+ \cdot 5692$ which is highly significant that is there is high positive correlation between temperature and population when R. H. remains constant. In the same way there is high positive correlation between R. H. and population when temperature is held constant because $+ \cdot 5585$, the partial correlation among them is highly significant.

The multiple correlation among population, average temperature and average R. H. is $+ \cdot 75$ which is also significant. Thus the temperature and R. H. are equally direct effective factors for the increase and decrease of population.

ACKNOWLEDGEMENTS

I wish to acknowledge my indebtedness to Dr. U. S. Sharga, the Head of Department of Zoology and Entomology, Agricultural College, Kanpur, who assigned the problem to me and under whose valuable guidance and supervision this investigation was carried out and to Dr. U. S. Srivastava of the University of Allahabad for very kindly going through the manuscript and for communicating it.

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APPENDIX I

(For observation in *juar* only)

Calculated values of standard error for the mean population and simple, multiple and partial correlation of R. H. (z), temperature (x) and population (y).

S. E.	=	\pm 263.8
r^{xz}	=	+ .61**
r^{yz}	=	+ .6748**
r^{xy}	=	+ .4630*
$r^{xy \cdot z}$	=	+ .5692**
$r^{zy \cdot x}$	=	+ .5585**
$r^{y \cdot zx}$	=	.75*

* = significant

** = highly significant

N. B.—For observations in *maize* only S. E. (\pm 1702) was calculated and correlations were not calculated because of the few number of readings.

APPENDIX 2

Calculated weekly average temperature and average R. H. corresponding to weekly observations on the population.

Sl. No.	Date of observation	Weekly average temperature	Weekly average R. H.
1	27-7-52	84	78
2	3-8-52	84	74
3	10-8-52	83	81
4	17-8-52	82	89
5	24-8-52	82	88
6	31-8-52	83	86
7	7-9-52	84	78
8	14-9-52	83	78
9	21-9-52	85	70
10	28-9-52	84	60
11	5-10-52	84	60
12	12-10-52	82	64
13	19-10-52	82	52
14	26-10-52	75	39
15	2-11-52	72	43
16	9-11-52	71	50
17	16-11-52	68	50
18	23-11-52	65	47
19	30-11-52	64	50
20	7-12-52	64	51
21	14-12-52	59	57
22	21-12-52	60	63

ON THE OCCURENCE OF ISOETES IN GYANPUR

By

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(Received on 4th February 1957)

Isoetes Coromandelina L. has been reported to occur in Varanasi (Bharadwaja 1935) and its morphology and anatomy has been studied in detail (Misra 1935). Later about its occurrence near Varanasi Misra (1946) writes, "A noteworthy point of geographical interest is the very local but abundant growth of *Isoetes Coromandelina* L. in the second zone of pool near the village Akhari. It has not been able to spread out to any of the neighbouring pools though seen there since 1931, and has not been reported so far from any other place in the province".

Recently in our studies of the vegetation of Gyanpur* and nearby villages we have discovered a very rich and luxurient growth of *Isoetes*. In a shallow pond in village of Taktaiya (which is about a mile west of Gyanpur) and, again, in the village Chaktoder, on its east side, in a tank (Chaktoder is about half a mile from Gyanpur) growth of this plant has been observed. It starts growing in August, attains luxurience in September and starts dying by the beginning of December. A few have been found, however to survive even upto the first week of January. The growth is restricted to a semiaquatic zone from where water starts receding in November and is almost completely dry in January. Soil has an approximate pH of 7.8.

The specimen on comparison with those of Varanasi has been found to be the same viz., *Isoetes Coromandelina* L.

It is noteworthy that its occurrence in Uttar Pradesh, hitherto supposed to be confined to Varanasi, has now been found to extend to villages round Gyanpur as well.

ACKNOWLEDGEMENT

Inspiration for carrying the present work is due to Dr. S. Ranjan, Professor of Botany, Allahabad University, Professor R. Misra of Banaras Hindu University and Dr. P. Maheswahari of Delhi University.

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*Gyanpur (25° 20' N; and 82° 28' E) It is 4 miles from Gyanpur Road Station of NE. Ry., station which is 38 miles west of Varanasi and 39 miles east of Allahabad City of the district of Varanasi of Uttar Pradesh State, India.

Dr. D. D. Pant, Assistant Professor of Botany, University of Allahabad inform the Academy in a communication that Shri Ram Asre, Plant Collector of the Botany Department, Lucknow University, has recently told him that he (R. A.) has found the *Isoetes* and *Ophioglossum* in a number of ponds around Lucknow also.

OBSERVATIONS ON THE FEEDING HABITS AND DIGESTION IN *MYLABRIS PHALERATA* PALL, THE BLISTER BEETLE (COLEOPTERA : MELOIDAE)

By

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(Received on 13th November 1957)

Mylabris phalerata, the blister beetle is known for its two-fold economic value, i.e., for the destruction it causes to a variety of flowers and for yielding an important commodity of commerce. Its adult is a pest of cucurbitous and malvaceous flowers and its dried elytra are used for the extraction of medicinal cantharidin ($C_{10}H_{12}O_4$). The study of its feeding habits and digestive physiology is, therefore, naturally of interest and importance, specially when it is well known that all control measures, particularly those dependent on stomach poisons, are dependent on their knowledge.

The insect is available in the fields from July to December and was collected for purposes of the present work mainly from flowers of *Luffa acentagula*, *L. aegyptica* and *Hibiscus esculentus* from August to November. Insects of both the sexes are equally abundant throughout this period.

Although the beetle is commonly found on flowers of *Luffa* sp., no special preference is shown for flowers of any particular species. Generally, they feed upon petals, but in cases of severe infestation anthers and pistils are also devoured with the result that fruit formation cannot take place, specially in case of flowers of the Malvaceae which are hermaphrodite in nature. However, in the case of the cucurbitous flowers, somehow the pests occur more abundantly on the male flowers.

As a rule, the feeding activity is most vigorous during early morning hours or in the late hours of the afternoons. During the day, when the sun is bright, the insects move to shady places, specially to flowers in such regions.

Adults starved for 10 to 12 hours require 3 hours to 3 hours, 40 minutes to consume completely one flower of *Luffa acentagula* or *L. aegyptica*, depending upon the size of the flower. Unstarved beetles take longer time and exhibit a tendency to shift from one flower to another and to feed only upon their petals.

Passage of food. The food passes from the mouth to outside through the anus in 1 hour to 1 hour 30 minutes, and defaecation takes place at an average interval of 10-37 minutes. For some reason, the time for the passage of food through the gut is slightly lesser in the males than in the females.

Determination of the Hydrogen-ion concentration. Since the quantity of secretion available in the different regions of the alimentary canal is very small, determina-

tion of the pH was made by the indicator paper feeding and indicator paper contact methods. Insects starved overnight were provided with moist bits of indicator papers of different ranges upon which they fed occasionally in small quantities. The insects were then dissected without water after regular interval, their alimentary canals cut open and the indicator paper removed on a clean dry slide. The pH in the different parts of the gut was then noted by comparison with the colour charts.

For the determination of the pH by direct contact, the adults were first starved for about four hours to clear the gut of its contents as far as possible. The insect was then dissected, its alimentary canal split open longitudinally and the indicator paper brought in contact with the inner wall of its different parts. The indicator paper was also brought in contact with the food contents of the different parts of the alimentary canal of the 'actively feeding' adults. The mean of these two results and that obtained by the paper feeding method has been given in Table 1. Each figure given in the table is the mean of five observations taken in the three ways mentioned above.

TABLE 1

pH in the different regions of the alimentary canal of *Mylabris Phalerata*

Region				Hydrogen-ion concentration
Foregut	...	...	...	6.0 — 6.2
Midgut	...	...	...	6.2
Hindgut	...	...	...	6.2
Excreta	...	...	...	6.0
Blood	..	...	...	6.4

Qualitative analysis of the enzymes in the alimentary canal. To analyse the different types of enzymes found in the different regions of the alimentary canal, the insects were dissected in double distilled water, the alimentary canal taken out in a depression slide and separated from other tissues and then its different parts washed in cold distilled water. Each part was then ground separately with a little glycerine and the extract thus prepared was transferred to a tube. Any suspended tissue in the extract was removed and a few drops of toluene were added to the extract to cover it at the surface and prevent it from the access of micro-organisms. The extract of each part was then incubated separately for each test at $35^{\circ}\text{C} \pm 1^{\circ}$. In each test, a control tube containing boiled tissue suspension was also treated under similar condition. Whenever distilled water was used, it was invariably boiled and cooled immediately before the experiment. As a rule, each test was performed about five times to confirm the results.

Tests for amylase, maltase, invertase and lactase were performed on the lines of Swingle (1928), those for lipase on the lines of Swingle (1930), the albumen test on the lines of Hinmann (1933) and the fibrin and peptone tests on the lines of Swingle (1928).

In the tests for lipase, 4 to 6 drops of the bromthymol blue solution (1%) was mixed with 25 ml. of 10% condensed milk solution and then 1% solution of KOH was added drop by drop till the solution turned blue. A few drops of the extract

were incubated with the milk solution thus prepared for 48 hours. Tests for proteases were performed at different pH values (6.4 to 8.5) but it was found that the enzymes acted only in alkaline medium.

The results of the various tests performed are given in Tables 2 to 7.

TABLE 2

Tests for the detection of lipase in the adult *Mylabris phalerata*

Tests performed	Salivary gland	Foregut	Midgut	Midgut contents	Hindgut	Excreta	Inference
Potassium iodide-iodine test	++++	-----	++++	++++	-----	-----	Amylase is present in the midgut and the salivary gland.
Picramic acid test	-----	-----	++++	++++	-----	-----	
Fluckiger test	-----	-----	++++	++++	-----	-----	

TABLE 3

Tests for the detection of maltase in the adult *Mylabris phalerata*

Tests performed	Salivary gland	Foregut	Midgut	Midgut contents	Hindgut	Excreta	Inference
Osazone test	-----	-----	++++	++++	-----	-----	Maltase is present in the midgut.
Barfoed's test	-----	-----	++++	++++	-----	-----	
Fluckiger test	-----	-----	++++	++++	-----	-----	

TABLE 4

Tests for the detection of invertase in the adult *Mylabris phalerata*

Tests performed	Salivary gland	Foregut	Midgut	Midgut contents	Hindgut	Excreta	Inference
Osazone test	-----	-----	++++	++++	-----	-----	Invertase is present in the midgut
Barfoed's test	-----	-----	++++	++++	-----	-----	
Fluckiger test	-----	-----	++++	++++	-----	-----	

TABLE 5

Tests for the detection of lactase in the adult *Mylabris phalerata*

Tests Performed	Salivary gland	Foregut	Midgut	Midgut contents	Hindgut	Excreta	Inference
Osazone test	-----	-----	++++	++++	-----	-----	Lactase is present in the midgut.
Barfoed's test	-----	-----	++++	++++	-----	-----	
Fluckiger test	-----	-----	++++	++++	-----	-----	

TABLE 6
Tests for the detection of lipase in the adult *Mylabris phalerata*

Test performed	Salivary gland	Foregut	Midgut	Midgut contents	Hindgut	Excreta	Inference
Condensed milk solution test	-----	-----	+++++	+++++	-----	-----	Lipase is present in the midgut

TABLE 7
Tests for the detection of protease in the adult *Mylabris phalerata*

Test performed	Salivary gland	Foregut	Midgut	Midgut contents	Hindgut	Excreta	Inference
Albumen test	-----	-----	+++++	+++++	-----	-----	Protease present in the midgut.
Fibrin test	-----	-----	+++++	+++++	-----	-----	Tryptic enzyme present in the midgut.
Peptone test	-----	-----	+++++	+++++	-----	-----	Proteolytic enzyme present in the midgut.

(The number of + or - signs in the tables represent the number of replications of each experiment.)

The above tables show the presence of amylase in the salivary glands, midgut and midgut contents and of maltase, invertase, lactase, lipase and a proteolytic enzyme in the midgut and midgut contents of the adult *M. phalerata*.

DISCUSSION

General speaking, the different parts of the alimentary canal of insects are neither strongly acidic nor strongly alkaline. But in the larvae and adults of blowflies and in the larvae of housefly (Hobson, 1931; Waterhouse, 1940; in aphids (Bramsdt, 1948) and in adult mosquitoes (MacGregor, 1931), the gut shows a strongly acidic reaction whereas in lepidopterous larvae (Shinoda, 1930, Waterhouse, 1949) and in trichopterous larvae (Shinoda, 1930b), it is weakly to strongly alkaline. In Coleoptera, Shinoda (1930b) and Staudenmayer (1940) have recorded both acidic and alkaline reaction in the midgut juice. Similar results have been recorded by the present authors in a number of beetles. In the present case, the pH of the gut ranges between 6.0 to 6.2 and there is no significant difference in the pH of the different parts of the alimentary canal.

Like other insects, in *M. phalerata* also only the salivary glands and the midgut have been found to be secretory in nature. The presence of amylase in the salivary gland and the midgut of this insect proves its capacity to utilise starch from the food it takes. Likewise, the detection of maltase, invertase, lactase, lipase and a tryptic type of proteolytic enzyme proves the power of the insect to utilise maltose, sucrose, lactose, fat and protein. The presence of lipase in the midgut extract may be correlated

with the fact that the insect feeds upon flowers, including the pistils which contains ovules which may be rich in fat. Hinmann (1933), Bramstedt (1948) etc., have concluded that protein is utilised completely along with sugars in the midgut of insects and Brown (1937) has demonstrated complete absence of protein from the excreta of *Melonoplus bivittatus*. In *Mylabris phalerata*, protein is digested by a tryptic type of enzyme which is active in the slightly alkaline medium present in the midgut.

SUMMARY

1. Adults of *Mylabris phalerata* feed on the petals of cucurbitous and malvous flowers and in severe cases destroys the sepals and pistils as well. They are found more commonly on various species of *Luffa*.
2. The pH of the foregut, midgut, hindgut and excreta of the insect is 6.0—6.2, 6.2, 6.2 and 6.0 respectively.
3. The salivary gland of the insect secretes amylase and the midgut amylase, maltase, invertase, lactase, lipase and protease.

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STUDIES ON THE ECOLOGY OF FRESHWATER FISHES OF INDIA:

PART I. SOME PHYSICAL, CHEMICAL, AND BIOLOGICAL INTER-RELATIONS

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ABSTRACT

The present paper makes an attempt for the first time in India to work out the ecology of freshwater fishes in terms of physical, chemical and biological inter-relations which have been worked out by the author as a result of such investigations for over five years. Fish-ecology has been worked out in the past in its descriptive aspect in India, but sustained work on quantitative and experimental ecology is attempted by the author. The waters of U. P. may be divided into the lotic perennial streams, monsoon streams, and irrigation channels; while the Lentic waters consist of lakes, ponds, and reservoirs. The perennial streams have both rheocolous and limnocolous fishes.

Physically, the lentic lakes may be divided into Oligotrophic, Entrophic and Dystrophic types in U. P.; while the lotic waters are cold-water hill streams, cool-water traibhabar streams and warm-water plain, waters. The total biomass of plankton is never very high when the temperature is low; while zooplankton is more affected by temperature than phytoplankton. *Chemically*, the lentic waters of U. P. are the highly alkaline and the almost neutral waters, the latter producing a better fish yield. A high oxygen concentration corresponds with phytoplankton peaks and increase in zooplankton causes decrease in oxygen content both of which affect the fish. Special niches exist in U. P. where lack of oxygen is the main limiting factor which has led to differential distribution of species in waters deficient in oxygen, giving rise to the air-breathing fishes. The phosphates and silicates have a direct bearing on phytoplankton peaks, since the values are high preceding a peak and drop sharply after each peak in U. P. (Fig. 5). Thus lack of phosphates and silicates means less growth for the young stages of almost all fishes of U. P.

Biologically, not only is there an inverse correlation between plankton and bottom fauna volumes, but there is also an inverse correlation between the biomass of zooplankton and phytoplankton during the year. Thus when one set of fishes are 'lieu' (e.g., plankton feeders or phytoplankton feeders), another set remain in 'fat condition' (e.g., bottom feeders or zooplankton feeders). The food chains of fish, as existing in the lakes of U.P., are compared with similar chains in the sea.

INTRODUCTION

Fish-ecology is the science of the responses of fishes to factors in the environment. It has three important aspects: (a) descriptive, (b) quantitative and (c) experimental (analytic and synthetic). *Descriptive ecology* is concerned with the knowledge relating to the mode of life of fishes—(i) their habits and preferences, (ii) the conditions under which they live, and (iii) the association of different species together. *Quantitative ecology* deals with the information relating to the measurement of the environmental requirements. This entails determination of (i) the extreme limits of toleration in the fluctuation of environmental factors, (ii) the demands that fishes make upon the environment for their own maintenance and increase, and (iii) the number and variety of species that can exist in particular habitats. *Experimental (Analytic and Synthetic) ecology* attempts to analyse the environment and its effects by varying particular factors under controlled conditions. It attempts to reconstruct the past and predict the future and also to examine the cause of the adjustments of fishes—why fishes have specific habitats, why fishes have acquired new limits of toleration for factors in the environment.

The Handbook of Indian Fisheries, Government of India (1951) says: "But the optimum conditions to be promoted and maintained in each kind of water, with regard to its hydrological factors, have still to be worked out. In farming practice very little is done towards preparation of waters before stocking, nor is much attention paid to the maintenance of suitable conditions after stocking." Studies on fish ecology help to tell the pisciculturist when, where, how, and with what to do his fish-culture. A good farmer sows his seeds after he has made sure of good soil and good manure; but fishery expansion programmes have up to now consisted in the main of seeding fresh expanses of water with fish-fry and fingerlings without determining the nature of the medium or the fertilisers needed where the seed is being sown, nor have optimum conditions been examined.

Day (1868, '74, '78, '89) in the nineteenth and Hora in the twentieth century, have been the main descriptive ecologists of bionomics and habits of Indian freshwater fishes. Hora (1933, '35, '36, '38, '40, '53) gave a bias to Indian Ichthyology as an ecological approach to the study of fish taxonomy. His bionomical studies on the game fishes Mahaseer, Pangas, Freshwater shark, Goonch, Silond, Bachwa, etc. are all well known. Besides, he made an intensive ecological study (1936) of the hill-stream fishes of India—although most of them are not of economic importance. Similar are his studies on the Gobioid fishes.

Other important studies in descriptive fish-ecology have been by Mookerjee (1946) and his school of Bengal; Das (1927, '35, '40) and his school in Hyderabad; the author (1955 A & B, 1956 A & B) and his Lucknow school; and a few stray workers (Job, 1940, '41; Khan, 1934; Chacko, 1945, '48, '54) in India and Pakistan. No sustained work on quantitative or experimental ecology has ever been done for the freshwater fishes of India. An attempt is now being made at Lucknow to work out this quantitative aspect, but the experimental ecological aspect is still unexplored. These ecological studies not only form the fundamentals of sound fish-culture but also help in Malaria, Guinea worm and Helminth eradication through biological control (Hora, 1938, '53). The author and his research assistants have already published part of their results in a series of papers dealing with fish-food feeding strata, gut modifications, plankton, hydrology and bottom fauna of lentic waters of U.P. Detailed data and tables of result will be published in a subsequent contribution, and only the main inter-relations are given here. (Das et al. 1955A, 1955B, 1955C, 1955D; 1956A, 1956B, 1956C, 1956D).

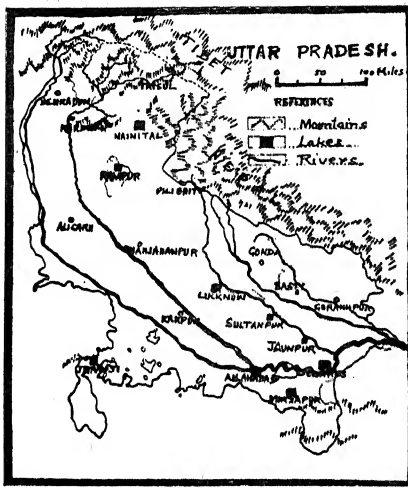


Fig. 1. Some fish sources of Uttar Pradesh.

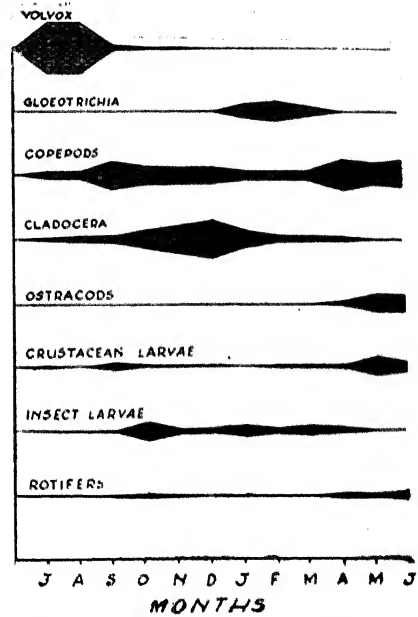


Fig. 2. The abundance of Plankton constituents, during the year.

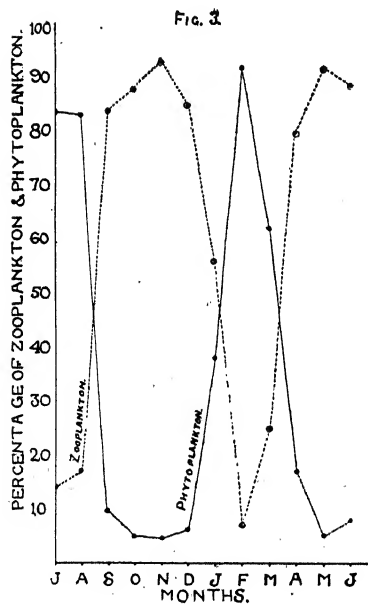


Fig. 3. The inverse correlation between zooplankton and phytoplankton.

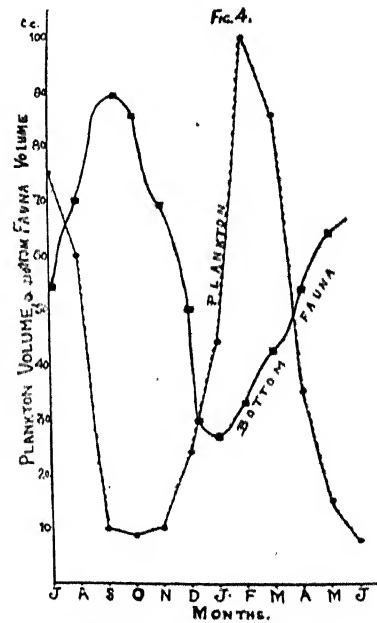


Fig. 4. The inverse correlation between Plankton volume and Bottom fauna volume.

CLASSIFICATION OF WATER BODIES

The waters of U.P. may be divided first of all into *Lotic* (or flowing) and *Lentic* (or standing) waters. The *Lotic* may be said to consist of: (a) the perennial streams (b) the monsoon streams and (c) the irrigation channels; while the *Lentic* consists of lakes, ponds, reservoirs and dams. The perennial streams have both *rhacoculous* and *limnoculous* fishes depending on whether the region is hill-region, sub-montagne region or plains region. The monsoon streams, although transient and muddy, harbour some fishes, while the irrigation channels have a fauna which may appear almost riverine in nature. Of the 3 kinds of lakes, *Oligotrophic*, *Eutrophic* and *Dystrophic*, only the *Eutrophic* lakes are abundant in U.P. The *Eutrophic* lake is shallow with green to yellow and brownish-green water, a large quantity of organic material is present at bottom or even suspended in the water, there is lack of oxygen in deep water in summer, the aquatic plants are abundant, and the basic fertility is high. The *Oligotrophic* lakes are found only in the hill-region of U. P. e.g., Naini Tal, Sat Tal, Bhim Tal etc. They have a relatively large amount of deep, cold water which is bluish to greenish and very transparent. There is little or no organic material in the deep water-bottom and the oxygen content is high at all depths at all seasons. The aquatic plants are few and basic fertility rather low; but it is a good habitat for cold water species. The *Dystrophic* lake is conspicuous by its absence in U.P.

Chemically speaking, the lentic waters may be broadly divided in U.P. into the highly *alkaline* and the almost *neutral waters*. The alkaline waters have a very low fish yield while the 7-8 pH ones have a good yield. Besides the pH, the yield of fish-food in these waters has been found to vary with the phosphate and silicate contents. The manifold gradations in chemical content, temperature, light and water current vary in different water bodies and there is a more far-reaching variation of living conditions in inland waters than in the seas around India (Das and Srivastava, 1956).

So far as fishes themselves are concerned they may be classified as *Fluvial* (stream-living), *Lacustrine* (lake-dwelling) and *Adfluvial* (living in still waters but leading to streams). The fluvial live the entire life in *lotic* waters. The lacustrine live the entire life in lentic waters; while the adfluvial live in lakes and ponds but ascend streams to spawn. The major carps of U. P. belong to the last category (adfluvial).

PLANKTON AND BOTTOM-FAUNA AS FISH-FOOD

The inland waters of U. P. exhibit a fauna which can be distinguished as *pedonic* (bottom) and *limnetic* (pelagic). The limnetic again consists of the passive surface *plankton* and the active *nekton*. The pedonic region in large lakes consist of a *paralimnic* or shore vegetation which goes down to a depth of 6-15 meters.

The *pedonic region* contains the richest and most diverse fauna in the lakes of U. P. as it furnishes a substratum for animals on its floor and on its plant forms. The plants supply shelter from enemies, protection against wave action, afford nourishment and liberate oxygen in large quantities. The shallowest region contains high-stemmed grasses and reeds and growths of rushes and sedges among them; next follows a strip of more strictly aquatic plants such as *Vallisneria*, *Nymphaea*, *Potamogeton*, and finally to completely submerged plants such as *Elodia*, *Chara*, *Hydrilla* etc. Protozoa, *Hydra*, flatworms, Annelids and Rotifers are specially abundant in this

region. With them also live the bottom crustacea-the Entomostraca, the Isopods and Amphipods. Besides there are large numbers of water-snails and mussels as well as larval insects (Srivastava, 1956). *Chironomus* larva reigns supreme in those water bottoms of U. P. which are deficient in oxygen, since this insect larva uses its red haemoglobin to utilize the small amount of oxygen present, and serves as a useful source of food supply when other sources fail.

The seasonal variation in *Pedonic fauna* is also remarkable. The maximum biomass of bottom fauna, as investigated by the author and his team, was during monsoon months, being mainly due to Oligochaetes, Chironomid larvae, Gastropods and Bivalves. The minimum is normally in January, which is the coldest month in U. P., when chironomid larvae and Oligochaetes alone thrive; while the other constituents such as Cladocera, Ostracods, Bivalves and Gastropods are much reduced. During the hot summer of U. P. i.e. in May and June there is a sudden rise in volume due to increase in Oligochaetes in the main. This is certainly in contrast with the American waters, where Eggleton (1931, '35, '52, '56) has shown a mid-winter maximum and a mid-summer minimum, a condition almost reverse to that found in N. India. Then again the composition of the lake shore-fauna is widely different in N. India from that in N. America where Cronk (1932) found molluscs to be the dominant group. In N. India three groups share this honour viz. the Oligochaetes, the Chironomid larvae, and the Molluscs.

The importance of bottom-fauna to fishes as food cannot be over-estimated. Das and Moitra (1955) have shown that a large percentage of the food of *Ophicephalus*, *Rita rita*, *Heteropneustes fossilis*, *Clarias batrachus*, *Labeo calbasu*, *Cirrhina*, and *Puntius sophore*, consisted chiefly of pedonic organisms. The larvae and young of many of these fishes are however plankton-feeders, as also found for the white-fish (Hart, 1931), the perch, and other fishes of N. America. The main oligochaetes represented in lentic waters of U.P. are *Aelosoma*, *Branchiodrilus*, *Chaetogaster*, *Dero*, *Nais*, and *Stylaria*. The aquatic insect larvae, besides *Chironomus*, are *Chaoborus* and *Dixa*. The molluscs are represented by species of the snails *Viviparae*, *Indoplanorbis*, *Gyrinus*, *Melanoidea*, *Limnaea*, *Planorbis*, and the bivalve *Lamellidens*.

The Crustacea are very abundant during and after the monsoon. The Ostracods are represented by *Eucypris*, *Stenocypris* and *Potamocypris*; the cladocera by *Daphnia*, *Ceriodaphnia* and *Bosmina*; while the smaller species of *Palaemon* dominate the Decapod population.

The Plankton of U. P. has only recently been worked out by Das and Srivastava (1955, '56). This important food of most young and many adult fishes has its largest biomass in July. The plankton shows a characteristic monsoon growth culminating in a monsoon peak. Then there is an Autumn decline during September and October, reaching an Autumn trough in November. There is a surprising winter growth, due mainly to phytoplankton, culminating in early spring peak in February. Finally, there is a summer decline in April and May leading to a summer trough in June.

Different plankton species dominate the plankton in the different seasons. July and August can be designated as *Volvox period*, September, October and November constitute the *Copepod period*, December and January as the *Cladoceran period*, February and March as *Myxophyceae period* and finally April, May and June as the *Ostracod period*. It has been found that there are two definite plankton peaks in U. P., and for that matter in the whole of N. India, one

in monsoon and the other in early spring. Finally, *there is an inverse correlation between the biomass of zooplankton and phytoplankton during the year; and this affects both the herbivorous and carnivorous fishes. There is also an inverse correlation between plankton volume and bottom fauna volume.*

HYDROLOGY AS A FACTOR IN FISH-ECOLOGY IN U. P.

All these are important data for fish-ecology in U. P., but yet more important is the sharp variation in plankton biomass due to differences in hydrological factors. Das and Srivastava (1956B) have established a definite correlation between plankton and the hydrological factors such as temperature, pH, oxygen, carbon-dioxide, phosphate and silicate values of the waters. The total biomass of plankton is never very high when the temperature is low. *In general zooplankton is more affected by temperature than phytoplankton which shows two peaks in July and February, while the zooplankton peaks occur only in July and November.* Similarly a decrease in H-ion concentration is associated with an increase in phytoplankton crop, while zooplankton peaks provide an increase in H-ion concentration.

Oxygen is the very life of freshwaters. As a matter of fact this single factor is more responsible for more vicissitudes in plankton, pedon and fishes, than any other single factor in hydrology. A high oxygen concentration corresponds with phytoplankton peaks, but this is not necessarily good for the fish, since many fishes may die of gills being clogged by the finer phytoplankton, during a phytoplankton bloom. On the other hand too much of zooplankton causes a decrease in oxygen content of the waters. In the smaller lentic water-bodies studied, where growth of aquatic plants is great, the water may become very low in oxygen due to accumulation and putrefaction of organic matter. This is similar to the results obtained by Juday and Birge in 1932 in U. S. A. Here only those fishes which have one or the other of accessory air breathing structures can survive, such as Singhi (*Heteropneustes*), Magur (*Glarias*), Vacha (*Eutropichthys*), Murrel (*Ophicephalus*) etc.

The phosphates and silicates have a direct bearing on phytoplankton peaks, since the values are high preceding a peak and drop sharply after each peak in U.P. Thus the lack of phosphates and silicates means less food and less growth for fishes, specially the young stages of most fish. This is also supported by the results of Juday and Birge (1931) in American waters.

THE NICHES

The biological niches for fishes, offered by the lotic and lentic waters of U. P., show a wide multiplicity of environmental conditions. Every gradation in water movement is found from the torrential foaming streams of the Himalayas to the broad lazily flowing streams of the plains, with the Terai Bhabar streams as moderate speed streams. The shallow clear water mountain streams offer a peculiar ecological niche in which the fishes show very characteristic adaptations, as shown by Hora (1936) in forms like *Glyptothorax*. A large part of the yield of fishes from rivers in Bengal, Madras and Bombay is furnished primarily by the migratory fishes coming up the rivers from the sea or going down to it.

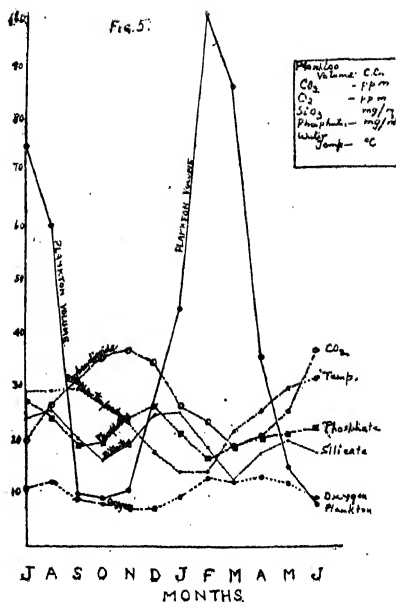


Fig. 5. Correlation of Plankton volume with CO_2 , Temperature, Phosphate, Silicate and Oxygen values of water.

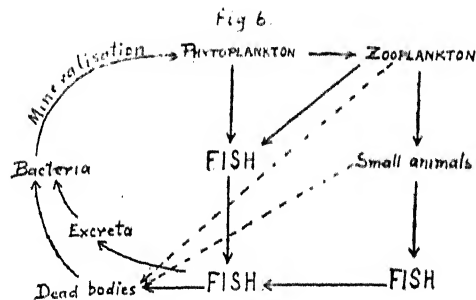


Fig. 6. Fish and food cycle in the sea.

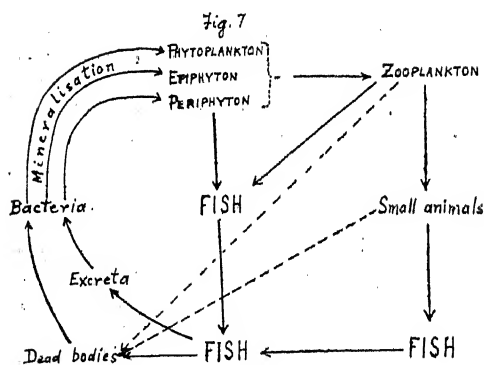


Fig. 7. Fish and food cycle in a lake.

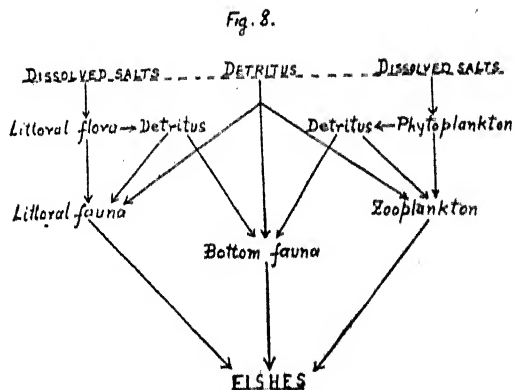


Fig. 8. Lake economy.

Even these show adaptation to particular niches e. g. surface-feeders, mid-feeders and bottom-feeders among them. But in U. P. the largest yield of fishes from rivers is by typical riverine or lacustrine fishes such as the large cat-fishes Tengan (*Mystus*), Parhan or Ganges shark (*Wallagonia*) Rita, Goonch (*Bagarius*), Seelan (*Silonia*) the carps Rohu (*Labeo*), Catla (*Catla*), Mirgal (*Cirrhina*); the feather-backs or chital (*Notopterus*) and the famous Mahaser (*Barbus tor*).

The lentic waters are also differentiated into various types with their characteristic fauna and flora. Here the cat-fishes, carps, live-fishes and minor barbs all compete with one another for food and shelter. This competition may have become detrimental to most species had they not selected particular ecological niches to remain apart from other species in feeding, breeding and shelter. Not all these niches have been worked out. But preliminary data reveal the demarcation into *surface-feeders*, *mid-feeders* and *bottom-feeders*. The surface-feeders, feeding mainly on plankton (the algae, rotifers, crustaceans and their larvae), are *Gadusia*, *Ailia*, *Catla*, *Ambassis*, *Callichrous*, and *Oxygaster*. The mid-feeders feeding on algae, plants, adult crustaceans, insects, fishes and mud and sand on the shore-line of lakes and tanks (species) are *Labeo*, *Amblypharyngodon*, *Mystus*, *Mastacembalus*, *Wallagonia*, and *Xenentodon*. The bottom-feeders, feeding mainly on decomposed aquatic vegetation, pedon insects and their larvae, crustaceans, molluscs, fishes, sand and mud, are *Cirrhina*, *Labeo* (species) *Puntius*, *Ophicephalus*, *Bagarius*, and *Rita*.

FISH FOOD CYCLES IN FISH ECOLOGY OF U. P.

No attempt to work out in detail the food cycles of fishes has been made in India. The studies on plankton and bottom fauna as fish-food in U. P. led the author to make a few preliminary studies on fish food cycles. We have seen that the natural food of fishes comes from the many groups of plants and animals that inhabit the waters. The animal, vegetable and mineral foods (containing proteins, carbohydrates, fats (lipids) and vitamins) are all present in the natural food, with certain elements such as calcium which is absorbed from the water itself.

The larval stages of most fishes studied feed on bacteria, desmids, diatoms and other microscopic plankton which later also includes plagic organisms such as algae, protozoa and plankton crustaceans. In still later stages, the diet of the fishes (e. g. carps) consists of *periphyton* and associated tiny animals forming a slimy coating on bottom plant stems, leaves, and debris. Thus even the completely herbivorous major carps are all omnivorous in early life.

It is only after becoming adults that fishes restrict their diet and become either herbivorous or carnivorous. But some remain omnivorous (infantile so to say) in their feeding habits throughout life; such are: *Puntius sophore*, *Eutropichthys vacha*, *Gadusia chapra* and *Rohitee cotia*. Their food consist of unicellular algae, filamentous algae, higher aquatic plants, rotifers, insects and their larvae, crustaceans, freshwater bryozoans and their statoblasts. The typical herbivorous fishes of U. P. are: *Labeo rohita*, *Labeo calbasu*, *L. goni*, *Cirrhina margila*, *Cirrhina reba*, *Catla catla* and *Amblypharyngodon mola*. The food of these fishes was found to consist of unicellular algae, filamentous algae and higher plants. Lastly, the carnivorous fishes studied were: *Mystus vittatus*, *Mystus cavassius*, *Callichrous pabda*, *Chela bacaila*, *Wallagoma attu*, *Ophicephalus striatus*, *Notopterus notopterus*, *Begarius begarius*, *Glossogobius giuris* and *Ambassis nama*. Their food consisted mainly of crustaceans (copepods and dephnids), insects and their larvae (water bugs, dragon flies and damsel flies), molluscs, fish and fish scales.

These feeding habits, as already elucidated by Das and Moitra (1956 A & B) are invariably reflected in the ratio between gut length and body length which is highest in the herbivores, falls considerably in the omnivores, and is lowest in the carnivores. The ratio is fairly constant for each of the species studied. Besides, this ecological food factor brings about marked modifications in the structure of the bucco-pharyngeal region and the alimentary canal. As examples may be cited *Labeo rohita* and *Labeo gonius* which are herbivores and have an edentulous mouth and long gill-rakers; the omnivores *Puntius sophore* and *Eutropichthys vacha*, the former has edentulous jaws like the herbivores but the gill-rakers are thorn-like, while, *E. vacha* has maxillary, mandibular and pharyngeal teeth and tooth-like gill-rakers as in carnivores; and finally in the carnivores *Notopterus chitala*, *Ophicephalus striatus* and *Bagarius bagarius* the jaws have six or seven types of highly specialised elaborated teeth for seizing, holding and tearing the food-prey, while the gill-rakers are also modified for grasping and preventing the escape of food, as also for rasping and crushing the same. All these recent observations have an important bearing on fish-ecology in India, since by a mere examination of the buccopharyngeal region and the gut-bodylength ratio we may tell with fair accuracy which fish is herbivorous, which carnivorous and which omnivorous. This will have an important bearing on the solution of fish food cycles.

Further, many of these fishes have still more restricted diet, in as much as some are mainly *entomophagous* (insect and insect larva eating), some *carcinophagous* (eating mainly crustacea), some *malacophagous* (eating molluscs in the main), and still others purely *cannibalistic*.

The food chains in the sea (as shown in Fig. 6) are three in the main, all three being inter-linked at one or more regions.

- (1) Phytoplankton → Fish → Fish → Dead bodies and excreta → Mineralisation → Phytoplankton.
- (2) Phytoplankton → Zooplankton → Fish → Fish → Dead bodies and excreta → Mineralisation → Phytoplankton.
- (3) Phytoplankton → Zooplankton → Small animals → Fish → Fish → Dead bodies and excreta bacteria → mineralisation → Phytoplankton.

But the food chains in a lake, as studied by the author (Fig. 7), have a further complication in the Phytoplankton being supplemented with *Epiphyton* and *Periphyton*, both of which constitute an important additional food at one stage or the other of the fish.

Finally an *ecological balance* is struck between dissolved salts, detritus, plankton, littoral fauna, benthic fauna and fishes (fig. 7). The dissolved salts play a very important role in Indian fresh-waters as shown in the present study. The plankton and the benthic fauna volumes are inversely proportional during the year; and thus when one set of fishes are lean, another set remains in a 'fat' condition. Again, the zooplankton and phytoplankton are inversely proportional in their occurrence during the year, thus helping to maintain a constant food-chain balance. Finally, there is a sharp fall in the phosphate-silicate values after each plankton peak; while each of the two plankton peaks is preceded by a steep rise in these dissolved salt values.

CONCLUSION

It has been found that carps become dwarfed and reach a third of their normal length when insufficient pedon is present. Most predaceous fishes live in the para-

limnic region. The bottom dwelling fishes show a number of convergent adaptations in members widely different taxonomically. The beard like feelers (barbels), the protruding mouth, secondarily formed gill filters, extension of anal fin whose undulations depress the head are all benthic adaptations in fishes such as *Mystus*, *Notopterus* and *Wallogonia*.

The result of all these adaptations has been such that fish-life of the smaller lentic water bodies is much like the larger lentic water bodies, but is usually richer in the number of individuals per unit area, when optimum conditions exist. *The yield from enclosed waters has been estimated at about 1000 lbs. (= 12½ maunds) per acre per annum in N. India.* But by sagacious utilisations of ecological data on fish species, this yield could surely be increased five-fold. And thus *studies on fish-ecology would not only establish the Science of Animal Ecology in India, but would also be of great economic importance to the country.*

European freshwater ecology can boast of such name as Muller, Fritsch, Forel, Simony including the first founders such as Swammardam, Leeuwenhoek and Reumur. Similarly American freshwater ecology has the names of Agassiz, Leidy, Forbes, Kofoid, Ward, Whipple, Birge, Marsh and Welsh. India, unfortunately has had few workers who can claim to be votaries of the science of Animal Ecology, which treats of the inter-relationships of organisms with their complete environment, and which has of late assumed prime importance in zoological studies all over the world. Hora and Das have given us some aspects of Indian Fish Ecology, but much remains to be done yet.

Finally, the most recent trend is the experimental work both in nature and in the laboratory. This is most desirable because it is high time the subject ceased to be purely observational and began to search causes. Factors vary in intensity and effectiveness. But they always vary in the presence of all the other factors of the environment. *No one factor ever operates alone.* The biotic community, including fishes, is within the grip of almost unbelievably complex inter-relationships. But these *inter relationships are orderly, logical and law-abiding*—not chaotic as it appears superficially. Therein lies the hope of man in his daring attempt to understand them.

ACKNOWLEDGEMENTS

The author is highly thankful to the Scientific Research Committee, U. P., for the grant of research schemes for investigations on fish-food, plankton, bottom fauna and hydrology of the water bodies of U. P., many of the results of which are incorporated in the present paper. Thanks are also due to the National Academy of Sciences, for promptly publishing the previous seven papers dealing with fish-food, plankton, hydrology and bottom fauna of lentic waters of U. P. by the author and his assistants at Lucknow.

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